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LGM-30B, STAGE II DISSECTED MOTORS TEST REPORT,(U)
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OGDEN AIR LOGISTICS CENTER
UNITED STATES AIR FORCE
HILL AIR FORCE BASE, UTAH 84056

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LGM-30B

STAGE II

DISSECTED

MOTOR

TEST REPORT

PROPELLANT ANALYSIS LABORATORY

MANPA REPORT NR 471(82)

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MANPA REPORT NR 471(82)

LGM-30B, STAGE II

DISSECTED MOTOR

TEST REPORT

Author

Daryl Anderson
DARYL ANDERSON, Chemist
Component & Combustion Test Unit

Engineering & Statistical Review By

Glenn S Porter
GLENN S. PORTER, Project Engineer
Service Engineering

Edward J. Erickson
EDWARD J. ERICKSON, Mathematician
Data Analysis Unit

Recommended Approval By

Leonidas A. Brown
LEONIDAS A. BROWN, Chief
Component & Combustion Test Unit

Approved By

Anthony J. Inverso
ANTHONY J. INVERSO, Chief
Propellant Analysis Laboratory

July 1982

Ind Products & Ldg Gear Division
Directorate of Maintenance
Ogden Air Logistics Center
United States Air Force
Hill Air Force Base, Utah 84056

ABSTRACT

This report contains the data obtained from testing propellant and case bond materials from four dissected Minuteman Stage II Motors. The tests conducted were in accordance with Service Engineering (MMWRBA) General Test Directive GTD-1 Dissect dated 28 June 1974. The directive specifies the tests required to elucidate any age induced problems which may affect the service life of the Stage II Motor.

Linear regression analysis was used to indicate trends of the test parameters. A representative regression plot was made of several parameters with each motor tested to date identified by different symbols. The regression analysis normally verified the trends established during the last test phase. Although there were some trend changes either from or to significant status, it does not seem likely that any problems of major concern are apparent at this time.

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GLOSSARY OF SYMBOLS AND TERMS

Symbol	Definition
Crosshead Speed	The rate of travel of the crosshead which pulls on a tensile specimen. Dimensions: in/min
CSA	Cross-sectional Area. Dimensions: in^2
DSC	Differential Scanning Calorimetry
D(t)	Creep Compliance - ratio between strain and stress at a given time following application of a constant stress. Dimensions: in/in/psi
DTA	Differential Thermal Analysis
E	Young's Modulus - ratio between stress (acting to change length) and the strain produced by this stress. It is calculated from a portion of the curve where stress and strain are linearly related. Dimensions: lbs/in^2
EGL	Effective Gage Length. Dimensions: in
em	Tensile strain (fractional change in length) at maximum stress. Listed as EM in G085. Dimensions: in/in
er	Tensile strain at rupture. Listed as ER in G085. Dimensions: in/in
E(t)	Stress Relaxation Modulus - ratio between stress and strain at a given time following application of a constant strain. Dimensions: lbs/in^2
F	The ratio of the sum of the deviations from the regression line to $(S_E)^2$. This calculated value is compared with a table of critical values to determine whether or not the variation from the regression line is significant.
γ	Cohesive Tear Energy. Dimensions: lb/in

GLOSSARY OF SYMBOLS AND TERMS (CONT)

Symbol	Definition
JANNAF	Joint Army, Navy, NASA & Air Force Committee
MAKPH	Propellant Laboratory Section, Ogden ALC
N	Number of test specimens represented
Ogden ALC	Ogden Air Logistics Center, Air Force Logistics Command
Linear Regression	A line with the general equation $Y = a + bx$ which best represents the trend of the mean test values with respect to time.
R	Linear Correlation Coefficient. It is the slope of the regression line corrected by the standard deviation of x over the standard deviation of y. The calculated value of R is compared with a table of critical values to determine whether or not the correlation of the samples is significant.
Sm	Maximum tensile stress (normal force per unit cross-sectional area). Listed as SM in GO-85, Dimensions: psi
Sr	Tensile stress at rupture. Listed as SR in GO-85, Dimensions: psi
S_y	Standard deviation (square root of variance)
S_B	Standard error of estimate of the regression coefficient.
S_E	Standard deviation of the data about the regression line (also $S_{y.x}$).
Strain Rate	The crosshead speed divided by the EGL. Dimensions: in/in/min
t	The ratio of the slope of the regression line to S_B. The calculated value of t is compared with a table of critical values to determine whether or not the slope of the regression line is significant.

GLOSSARY OF SYMBOLS AND TERMS (CONT)

Symbol	Definition
TCLE	Thermal Coefficient of Linear Expansion. Dimensions: in/in/^{o}C
T_g	Glass Transition Temperature. Dimension: ^{o}C
TGA	Thermogravimetric Analysis
Variance	The sum of squares of deviations of the test results from the mean of the series after division by one less than the total number of test results.
3-Sigma Band	The area between the upper and lower 3-sigma limits. Presuming normal distribution, it can be expected that 99. of the inventory represented by the te samples would fall within this range.
90-90 Band	Assuming normal distribution, it can b stated with 90% confidence that 90% of the inventory represented by the test samples would fall within this range.
Significant	As used in the statistical sense, means a difference unlikely to have been the result of random sampling from some specified population.
S.D.	Standard Deviation

INTRODUCTION

PURPOSE: The purpose of this program was to continue the surveillance testing of Minuteman "Safeguard" Stage II Propellant. This surveillance will elucidate the aging characteristics of the propellant and, using statistical trends derived from the testing, establish the service life of the motor.

BACKGROUND: Surveillance testing was initiated in 1963 on cartons of propellant cast from the same propellant used in motor manufacture.

In 1971, all laboratory prepared insulation material and case to propellant bond specimens were destroyed in a conditioning chamber malfunction. The number of cartons of propellant was also near depletion, which would terminate the surveillance program.

A force modernization program made available some older Minuteman I Stage II motors. Three of these motors were selected to represent the motor inventory and were dissected for laboratory surveillance testing. The motors selected were S/N 0022135, cast in June 1963; S/N 0022583, cast in January 1964; and S/N 0022788, cast in July 1964. An additional motor, S/N 0022687, cast in April 1964, became available and was dissectioned in 1981 for continuing surveillance testing.

The amount of propellant available from motor S/N 0022583 was sufficient for only four test periods. Motors S/N 0022135 and S/N 0022788 contained sufficient propellant for seven (7) test periods. To date, six annual test periods have been completed on an annual basis.

No insulation materials from the three motors were available for testing since all materials were depleted during the fourth test period.

DISSECTION: Motors /N 0022135, S/N 0022583 and S/N 0022788 were dissected and cut into sections and then guillotined into segments as illustrated in figures 1 and 2 respectively. Motor S/N 0022687 was dissectioned in a similar manner except the distance between cuts B and C, and cut C and D was increased to 19 inches so that only two segments were received rather than three segments from previously dissectioned motors.

Motors which have been dissected to date are:

Motor S/N	Cast Date
0022135	63162
0022583	64008
0022788	64197
0022687	64096

The segments, which were tested during this phase, were taken from section 4. Segments C, D, and E were used for motor S/N 0022135 and segments E, G, and L were used for motor S/N 0022788. Segments A, B, and C were used for the first time testing of motor S/N 0022687. The samples were cut in their respective orientation as illustrated in figure 3. Figure 4 illustrates the cutting plan for this test phase.

STATISTICAL ANALYSIS

The objective of this statistical analysis is to determine whether or not any aging trends are demonstrated by accumulated test data in order to assist Service Engineering to more accurately predict motor serviceability.

Propellant was made available for testing and statistical analysis to obtain an overall view of the aging trends affecting the Second Stage Dissected Motor Program. In the past, carton data and dissected motor data were combined to yield sufficient samples to perform the analysis. Since there is now sufficient dissected motor data, carton data will not be included in the analysis. This will eleminate a further biasing factor in the results.

A Multi-symbol Regression Analysis Program was used to determine aging trends. The sampling is combined for each test parameter in a single regression analysis. The linear equation ($Y = a + bX$) was found to be the best fit model for the data in this report. A composite population aging trend line was then calculated accepting the fact that individual aging of different motors may be masked.

The Multi-symbol Program uses a unique plotting code for each motor on the regression plots. This method of data plotting allows a visual display of the overall relationship between motors and how they relate to the overall least square aging trend line.

The regression program uses an analysis with individual data points from different time periods combined to establish a least squares aging

trend line for the overall data. The variance about the regression line, obtained using individual values of the dependent variable, was used to compute a tolerance interval such that at the 90% confidence level 90% of the population falls within this interval. This tolerance interval was extrapolated to a maximum of 24 months to give an indication of the statistical significance of the slope of any aging trends. The computed tolerance interval about the composite regression line is wider than what the tolerance interval would be about any individual motor regression line because of the increased data spread introduced by combining data from different motors. The 't' values and the significance of this statistic, which are reported for each regression model, gives an indication of the "statistical significance" of the slope of the aging trend in the Y=axis. A slope of the trend approaching a zero slope will be indicated as being "statistically not-significant." Data and regression trend lines were plotted utilizing an IBM-360/65 computer.

The accuracy of the statistical inference improves as the sampling becomes larger. An analysis of the slope of the trend lines revealed the majority are becoming flatter:

Motor	Symbol
0022135	⊡
0022583	⊙
0022788	△
0022687	*

DEFINITION OF THE MASTER STRESS RELAXATION CURVE

The master stress relaxation curve is a composite curve representing the behavior of a polymer over a wide range of time and temperature relationships. From a curve constructed at a given strain level, any combination of time and temperature can be used to determine a corresponding stress relaxation modulus.

DETERMINATION OF STRESS RELAXATION MODULUS USING A MASTER STRESS RELAXATION CURVE

From test data at a particular strain level, a polymer's stress relaxation modulus corresponding to any combination of time and temperature can be determined. The horizontal axis of the master stress relaxation plot is a logarithmic value (t/a_T), and the vertical axis is a linear value, E(t) 298/T, where E(t) is the stress relaxation modulus dependent on time. T is temperature in degrees Kelvin, a_T equals any relaxation time at temperature T divided by the corresponding time at the reference temperature (298 degrees Kelvin or 77^{o}F), and 't' is relaxation time in seconds. The stress relaxation modulus for any combination of temperature and time can be determined by using the following steps:

a. For each stress relaxation plot there is associated a plot of temperature in degrees F versus log a_T. From this plot, determine log a_T corresponding to the temperature at which stress relaxation modulus is desired.

b. Determine lot 't' or log of the desired stress relaxation time.

c. Determine lof (t/a_T) by using the equation:

$$\log (t/a_T) = \log t - \log a_T.$$

d. Place the determined value of log (t/a_T) in the horizontal axis of the large plot and reference the master stress relaxation curve to determine the corresponding value E(t)298/T in the vertical axis.

e. Determine 298/T and divide into E(t)298T to find E(t), the stress relaxation modulus at the desired time and temperature.

TEST RESULTS

A change in the testing program was initiated during this test phase with the dissection of another second stage "Safeguard" Minuteman motor. The change substantially reduced the amount of tensile testing performed on the propellant. Therefore, the amount of regression analyses which have been previously reported will not be included in this and future reports.

A. UNIAXIAL TENSILE TEST:

The result of the uniaxial tensile testing are summarized in Table 1. Representative plots of those regression analyses which had sufficient data to provide meaningful statistical trends are presented as figures 5 thru 16. The significance of the regression trend line slopes have been summarized and are presented in Table 3. The direction of the trend line slope is indicated by a + or - sign after those slopes which are significant.

A comparison of the regression results of this test phase with the analysis from the previous test phase indicates very little change in the significance of the trend line slopes. The only changes that have occurred are: (1) the strain at rupture for the outer propellant tested at 2.0 in/min changed from a not significant to a significant status in the positive direction during this test phase; (2) the strain at rupture and modulus of the inner propellant tested at 0.0002 in/min changed from a significant to a not significant status; (3) the maximum stress and modulus of the inner propellant tested at 2.0 in/min changed from a significant to a not significant status during this test phase.

B. BIAXIAL TENSILE TEST:

The results of the biaxial tensile testing are also summarized in

Table 1 and the regression analysis plots are presented in figures 17 thru 22. The only changes in the regression trend line slopes occurred in the outer propellant strain at rupture and modulus parameters which changed from a not significant to a significant status during this test phase. This change in significance does not necessarily indicate a change in the propellant which would adversely affect the shelf/service life of the motor.

C. HIGH RATE HYDROSTATIC UNIAXIAL TENSILE TEST:

The data from the high rate tensile test at 500 psi initial test pressure are summarized in Table 1. The regression plots are presented in figures 23 thru 28. A comparison of the regression trend lines with the previous test phase regressions indicated no change in the significance of the trend line slopes.

D. CIRCUMFERENTIAL TENSILE TEST:

The results of the tensile testing of the specimens cut in the circumferential orientation are summarized in Table 1. The regression analyses are presented as figures 29 thru 31. A comparison of the circumferential data with the corresponding uniaxial data indicated no differences in the maximum stress and stress at rupture. There is little difference in the strain at maximum stress and strain at rupture at the very low strain rate. However, the strain properties do become noticeably different at the higher strain rate.

E. BI-PROPELLANT TENSILE TEST:

The results of the bi-propellant tensile tests are summarized in Table 2. The regression plots are presented in figures 32 thru 34. The failure mode of the two propellant specimens did not occur in the propellant/propellant interfacial bond. The failures occurred in either the ANP-2862 propellant or the ANP-2864 propellant depending upon the motor being tested.

The propellant with the lower tensile strength was normally the propellant in which the bi-propellant specimen failed.

F. STRESS RELAXATION PROPERTIES:

The stress relaxation data are summarized in Table 4. Representative regression plots for the 3% strain rate are presented in figures 35 thru 42. A master stress relaxation curve, constructed from the surveillance data is presented in figures 43 thru 46. The definition and a description on the use of the master stress relaxation curve is given in the statistical analysis section.

Bond failures occurred in the stress relaxation specimens before the specimens could be loaded to the three and five percent strain rates at the lower test temperatures, -65 and occassionally -40°F. Rebonding the specimens to the test fixtures and retesting the specimens resulted in erroneous data and therefore was not included in this report. A better bonding compound will have to be found or developed before the next test phase so that adequate data can be obtained for the low temperature tests.

G. MINITHIN TENSILE TEST:

The minithin tensile specimen is used primarily for profile analysis. Propellant ingredients sometimes migrate from the propellant into the liner and/or insulation. Migration may also occur in the opposite direction e.g. liner or insulation ingredients may migrate into the propellant. This migration process may adversely affect the propellants physical properties or the propellant to liner interfacial bond. The minithin tensile specimen will detect the effect the migration ingredients have on the propellants properties and the depth of the effect. Similarily, minithin tensile specimens taken from the bore will detect the effect atmospheric

conditions have on the propellant.

Minithin tensile specimens were obtained from three separate locations at the propellant/liner interface and from three starpoint locations. The results of the minithin testing are summarized in Table 5 for the three motors tested.

The results for the propellant/liner interface specimens indicate no migration or propellant/liner interactions are occurring that can be detected by physical property testing. The minithin specimens taken from the bore area do indicate a trend for the first 3 or 4 specimens, which represent 0.3 to 0.4 inches into the propellant web, for all three motors. However this trend should be verified with additional testing before much reliance may be placed in it.

H. BURN RATE:

The burn rate data, at an initial pressure of 500 psi, for this test phase are summarized in Table 6. The regression analysis of the data accumulated to date is presented in figures 47 and 48 for the outer and inner propellant respectively. There was no change in the significance of the regression trend line slope. The burning rate of the outer (ANP-2862) continues to exhibit a positive trend line slope that is statistically significant. The inner (ANP-2864) propellant continues to exhibit a trend line slope that is not significant.

I. TCLE: (1) Propellant:

The Thermal Coefficient of Linear Expansion test consists of measuring the amount of expansion below and above the glass transition point of the polymer used in the manufacture of the propellant. The regression plots are presented in figures 49 thru 52 and the data obtained during this test period is summarized in Table 6.

The regression trend line did not change significantly for the outer propellant below the glass transition point (Tg). However, it did change from a not significant to a significant status above the Tg point. There was no change in the trend line slope for the inner propellant.

(2) Rubber:

The TCLE could not be accurately performed due to the natural curl in the rubber insulation obtained from the head-end of motor 22687. The rubber specimens from motors 22135 and 22788 were taken from the casebond specimen areas without success. Attempts to separate the rubber from the case resulted in a rubber surface that was very rough and was not parallel with the liner/rubber interface surface. Because of the TCLE rubber specimen condition, it was decided to void the testing and use the specimens for moisture, swell ratio and gel fraction testing.

J. HARDNESS:

The Shore A hardness of the outer and inner propellant has a considerable amount of scatter in the data accumulated during the surveillance program. However, the regression analysis does not indicate a significant trend although the slope of the trend line indicates a softening of the outer propellant and an increasing hardness for the inner propellant. The regression analysis plots are presented in figures 53 and 54 for the outer and inner propellants respectively.

K. SWELL RATIO, GEL FRACTION and MOISTURE:

The liner and rubber swell ratio, gel fraction and moisture specimens were obtained from the head-end area. The specimens for motors 22135 and 22788 were obtained from the casebond specimen area of section four.

The results of the testing are summarized in Table 6. There was con-

siderable amount of variance in the rubber swell ratio and the gel fraction, but the average of the data, which is reported in Table 6, are in fairly good agreement e.g., there was more variance between specimens than there was between motors. The liner data was consistant without a large amount of specimen variance.

L. SHEAR and TENSILE AVCOAT PROPERTIES:

The results of the shear and tensile testing of avcoat and composite specimens, e.g., avcoat, case, insulation liner, and propellant specimens, are summarized in Table 7. The failure mode of the avcoat specimens occurred in the secondary bonding area of the avcoat to test fixture with no indications of any avcoat or avcoat to case failure. The bond strength of the avcoat to steel case is naturally higher than the data indicates. The failure of the composite specimens occurred cohesively in the propellant about 50% of the time and adhesively between the liner and propellant about 48% with 2% cohesive liner failure.

M. CONSTANT LOAD TEST:

The results of the constant load test varied considerably and, therefore, are not included as raw data. However, a mathematical treatment of the raw data produced a trend line for each of the three motors tested, which appears as figures 55, 56, and 57 for motors 22135, 22687, and 22786 respectively. As more trend lines are accumulated, a regression analysis will be performed on the trend lines to determine if changes are occurring in the constant load strength of the composite interfacial bonds.

The average stress at 100 minutes is presented in Table 7.

CONCLUSIONS

The regression analyses of all data obtained to date from the physical testing have indicated a majority of the test parameters do not have significant trend line slopes. The significance of some slopes have changed from significant to not significant while other trend line slopes have changed from not significant to significant. The significance of a slope does not necessarily indicate a deterioration in the propellant or a propellant, liner, insulation, casebond problem. An increasing slope may indicate an improving parameter.

There were no apparent problems observed that would indicate any areas which affect motor performance or service life.

TABLE 1

TENSILE TEST PARAMETERS
1982 Mean Values

Motor S/N	Test	CHS	OUTER Sm	OUTER em	OUTER er	OUTER Sr	OUTER E	INNER Sm	INNER em	INNER er	INNER Sr	INNER E
		(in/min)	(psi)	(in/in)	(in/in)	(psi)	(psi)	(psi)	(in/in)	(in/in)	(psi)	(psi)
	Uniaxial Tensile											
0022135		.0002	37	.176	.235	29	305	47	.274	.352	42	258
		2.0	99	.193	.560	61	1090	124	.296	.583	94	967
0022687		.0002	44	.192	.232	41	330	47	.336	.407	43	186
		2.0	130	.388	.592	109	944	120	.478	.711	107	679
0022788		.0002	40	.207	.255	36	301	40	.271	.305	38	205
		2.0	104	.300	.544	80	844	103	.345	.697	76	585
0022135	Biaxial	0.20	90	.163	.290	70	858	113	.247	.394	90	715
0022687	Tensile		101	.309	.409	92	688	117	.434	.529	111	477
0022788			93	.275	.425	77	699	94	.324	.486	78	443
0022135	Hydrostatic	1750	535	.271	.390	499	7220	571	.367	.536	531	6560
0022687	Tensile	@500 psi	562	.330	.415	546	7230	606	.506	.665	583	5450
0022788			514	.327	.452	484	5290	548	.437	.574	572	4710
0022135	Circumferential	.0002						49	.279	.304	47	241
	Uniaxial	2.0						124	.412	.527	113	733
0022687	Tensile	.0002						47	.336	.407	43	186
		2.0						128	.691	.769	120	574
0022788		.0002						45	.297	.310	44	184
		2.0						117	.458	.552	110	549

TABLE 2

BI-PROPELLANT TENSILE TEST
1982 Mean Values

Motor S/N	Test	CHS (in/min)	Sm (psi)	em (in/in)	er (in/in)	Sr (psi)	E (psi)
0022135	Hydrostatic Tensile	1750 @ 500 psi	527	.383	.456	516	6320
0022687			504	.369	.470	486	6040
0022788			495	.337	.479	479	6630
0022135	Uniaxial Tensile	.0002	31	.179	.202	29	236
0022687			36	.213	.235	34	233
0022788			39	.246	.280	37	238

TABLE 3

REGRESSION SUMMARY

A. Tensile Properties:

Test	CHS (in/min)	OUTER Sm	OUTER er	OUTER E	INNER Sm	INNER er	INNER E
Uniaxial Tensile	.0002	NS	NS	NS	S+	NS	NS
	2.0	S+	S+	NS	NS	NS	NS
Biaxial Tensile	0.2	S-	S+	S-	NS	NS	NS
Hydrostatic Uniaxail Tensile	1750 @ 500 psi	S+	NS	S+	S+	S-	S+

B. Physical Properties:

	OUTER	INNER
Burn Rate	S+	NS
TCLE Below Tg	S+	S+
Above Tg	S+	S+
Hardness Initial	S-	S-
10 sec	NS	NS

C. Other Propellant Properties:

Circumferential	0.0002	NS	NS	NS
Bi-Propellant	0.0002	S-	NS	NS

TABLE 4

STRESS RELAXATION PROPERTIES

Motor SN	Strain Rate	Temp (°F)	OUTER 10 (psi)	OUTER 50 (psi)	OUTER 100 (psi)	OUTER 1000 (psi)	INNER 10 (psi)	INNER 50 (psi)	INNER 100 (psi)	INNER 1000 (psi)
0022678	3%	-65	*				872	587	499	298
		-40	375	219	175	78	463	272	218	93
		20	49	29	24	13	44	24	19	10
		77	15	11	10	7	16	11	10	8
		120	12	10	9	7	11	9	8	7
		160	8	7	6	5	9	8	7	6
	5%	-65	*				*			
		-40	328	187	148	61	468	272	216	93
		20	80	44	36	20	70	39	32	16
		77	28	20	18	14	26	19	17	13
		120	16	13	12	10	19	15	14	11
		160	15	13	12	9	16	14	13	11
0022135	3%	-65					912	885	792	502
		-40	385	335	280	146		391	346	197
		20	57	33	27	16	72	43	36	22
		77	17	13	11	9	22	16	15	11
		120	11	9	8	7	18	15	14	11
		160	9	8	7	6	15	13	12	10
	5%	-65	-	-	-	-	-	-	-	-
		-40	355	211	171	87	466	288	238	128
		20	94	47	39	22	117	63	52	31
		77	29	21	19	15	35	26	24	18
		120	20	16	15	12	25	19	18	16
		160	16	14	13	10	24	20	19	16
0022788	3%	-65	-	-	-	-	-	-	-	-
		-40	385	268	220	110	394	320	266	135
		20	56	32	26	15	53	29	22	12
		77	15	11	10	7	12	9	8	6
		120	11	9	9	7	9	8	7	6
		160	8	7	6	5	8	7	7	5
	5%	-65	-	-	-	-	-	-	-	-
		-40	-	-	-	-	-	-	-	-
		20	84	42	34	19	90	43	34	18
		77	28	20	18	14	19	14	13	10
		120	16	13	12	10	15	13	12	10
		160	15	12	12	9	13	11	11	8

*Bond failure occurred before specimen could be loaded to respective strain rate.

TABLE 5

MINITHIN TENSILE DATA
1982 Mean Values

Distance x0.1 in	Motor 0022135 Bore (psi)	Motor 0022135 Liner (psi)	Motor 0022687 Bore (psi)	Motor 0022687 Liner (psi)	Motor 0022788 Bore (psi)	Motor 0022788 Liner (psi)
1	126.0	78.1	111.9	86.6	89.7	92.8
2	132.9	79.3	117.2	87.1	104.7	93.0
3	134.3	78.4	118.6	86.3	110.1	92.2
4	135.5	78.9	119.9	86.8	109.1	92.7
5	134.4	79.1	120.4	86.4	110.7	91.6
6	134.8	80.2	119.5	86.1	108.9	91.7
7	133.7	81.6	118.4	86.6	107.7	91.5
8	133.5	83.2	118.2	86.3	107.7	91.0
9	133.1	83.5	119.5	86.5	107.4	91.4
10	131.4	83.7	120.4	86.3	108.3	91.2

TABLE 6

PHYSICAL PROPERTIES
1982 Mean Values

Test		Motor 0022135	Motor 0022687	Motor 0022788
Burn Rate				
Outer Prop		.307	.297	.259
Inner Prop		.378	.358	.368
TCLE (in/in x 10^{-5} °C)				
Outer Prop	Above Tg	9.69	10.20	9.61
	Tg	-52	-56	-55
	Below Tg	6.17	6.29	6.36
Inner Prop	Above Tg	9.57	9.82	9.28
	Tg	-54	-58	-55
	Below Tg	6.02	6.44	6.52
Hardness				
Outer	Initial	76	77	79
	10 sec	63	69	68
Inner	Initial	72	74	78
	10 sec	61	62	70
Swell Ratio				
V44		1.38	1.47	1.28
Liner		2.37	2.42	2.40
Gel Fraction				
V44		91.14	89.69	89.35
Liner		62.10	63.37	65.45
Moisture (%)				
V44		0.84	0.92	0.72

TABLE 7

AVCOAT PROPERTIES
1982 Mean Values

Test and Conditions	Motor 0022135	Motor 0022687	Motor 0022788
Hardness Shore D		83	
Shear Strength Avcoat (psi) 2 in/min @ 500 psi	1443	1381	
Shear Strength Composite (psi) 2 in/min @ 500 psi	150	171	163
Tensile Strength Composite (psi) 20 in/min @ 500 psi	491	508	427
Tensile Constant Load 100 min Stress (psi)	33.5	37.8	27.6

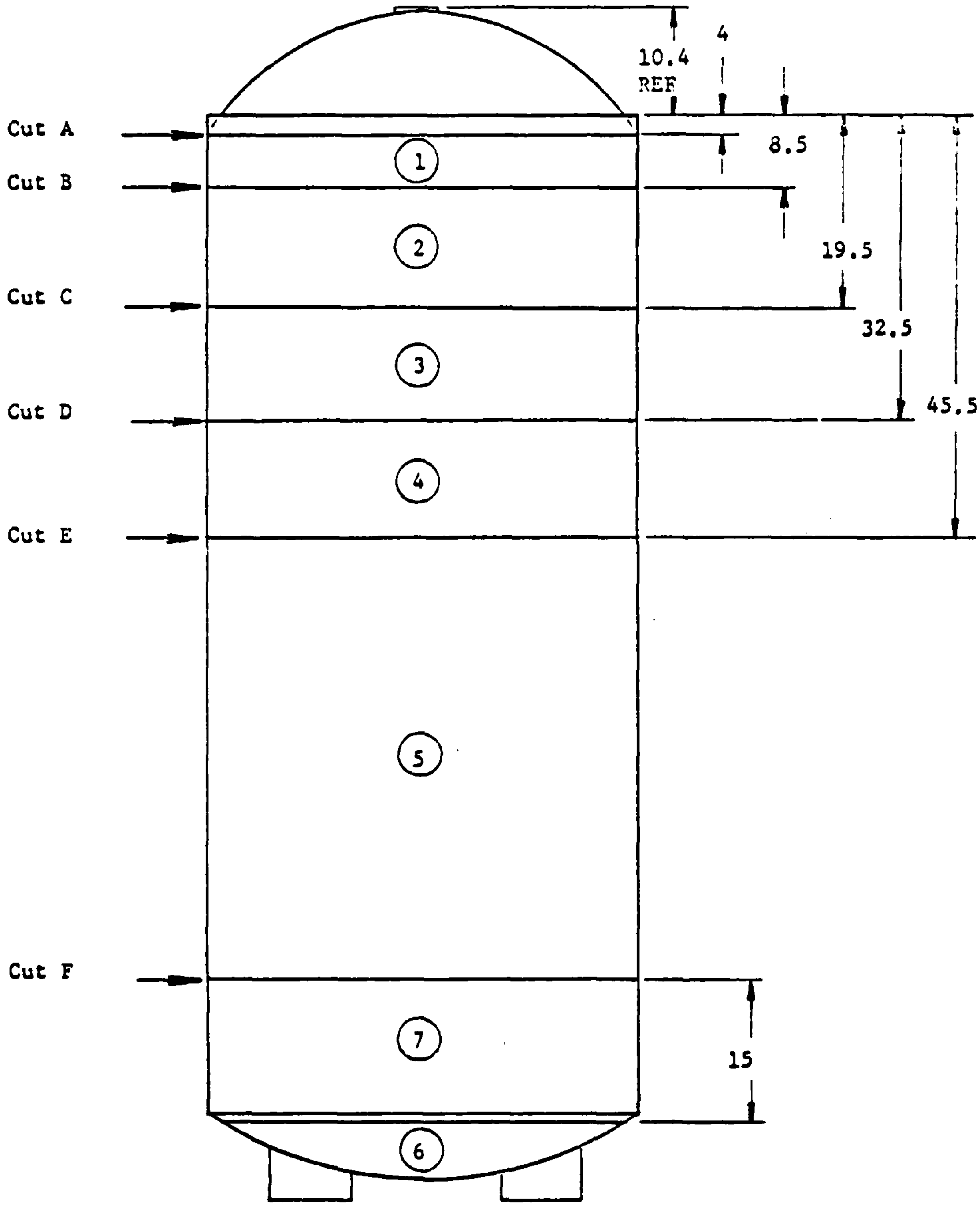


Figure 1 Dissection layout of Cuts, Locations and Section Numbers

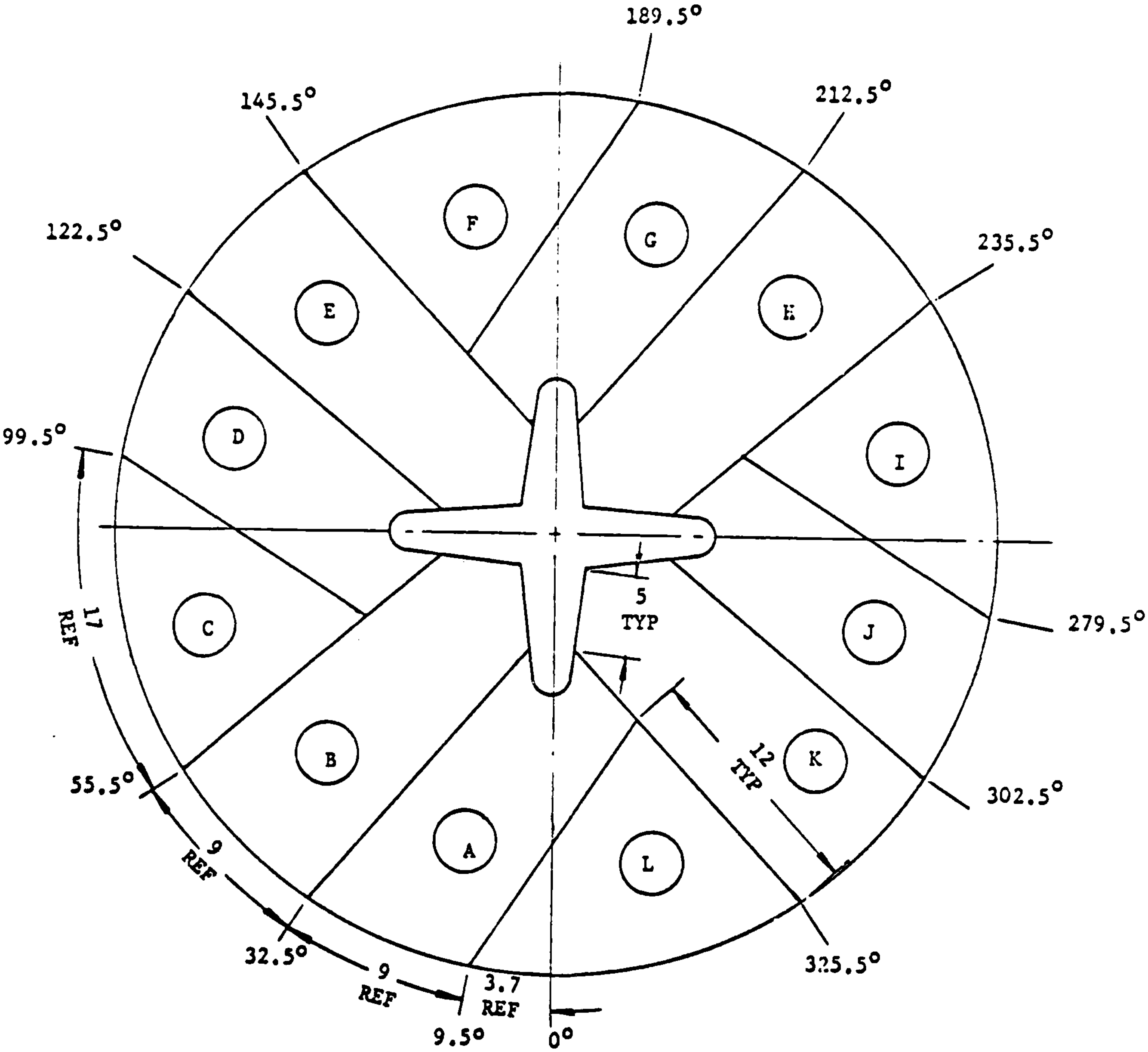


Figure 2 Section 3 and 4 Segment Layout and Letter Identification

This figure illustrates what the various sample orientation terms mean with respect to a segment of the motor.

A JANNAF dogbone is used in the illustration to depict the areas from where the specimens are obtained.

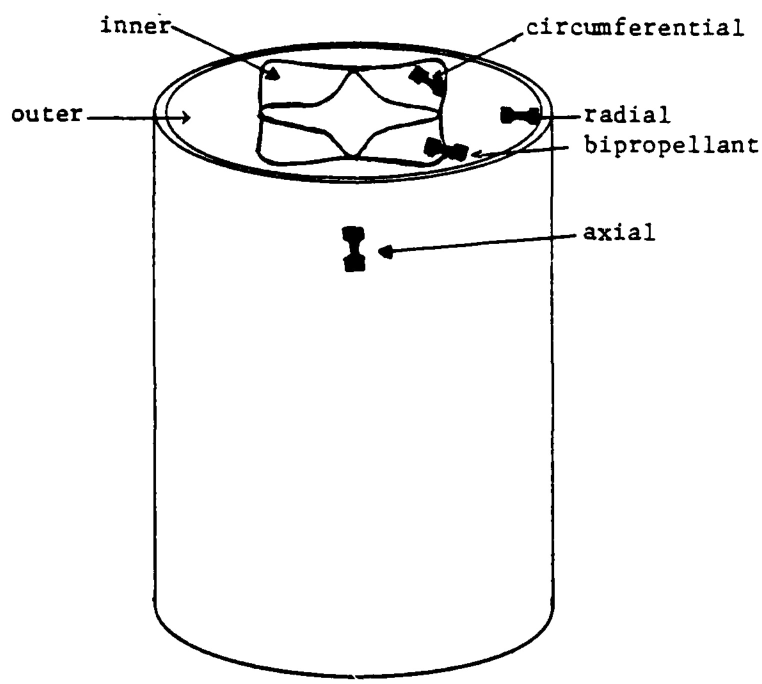
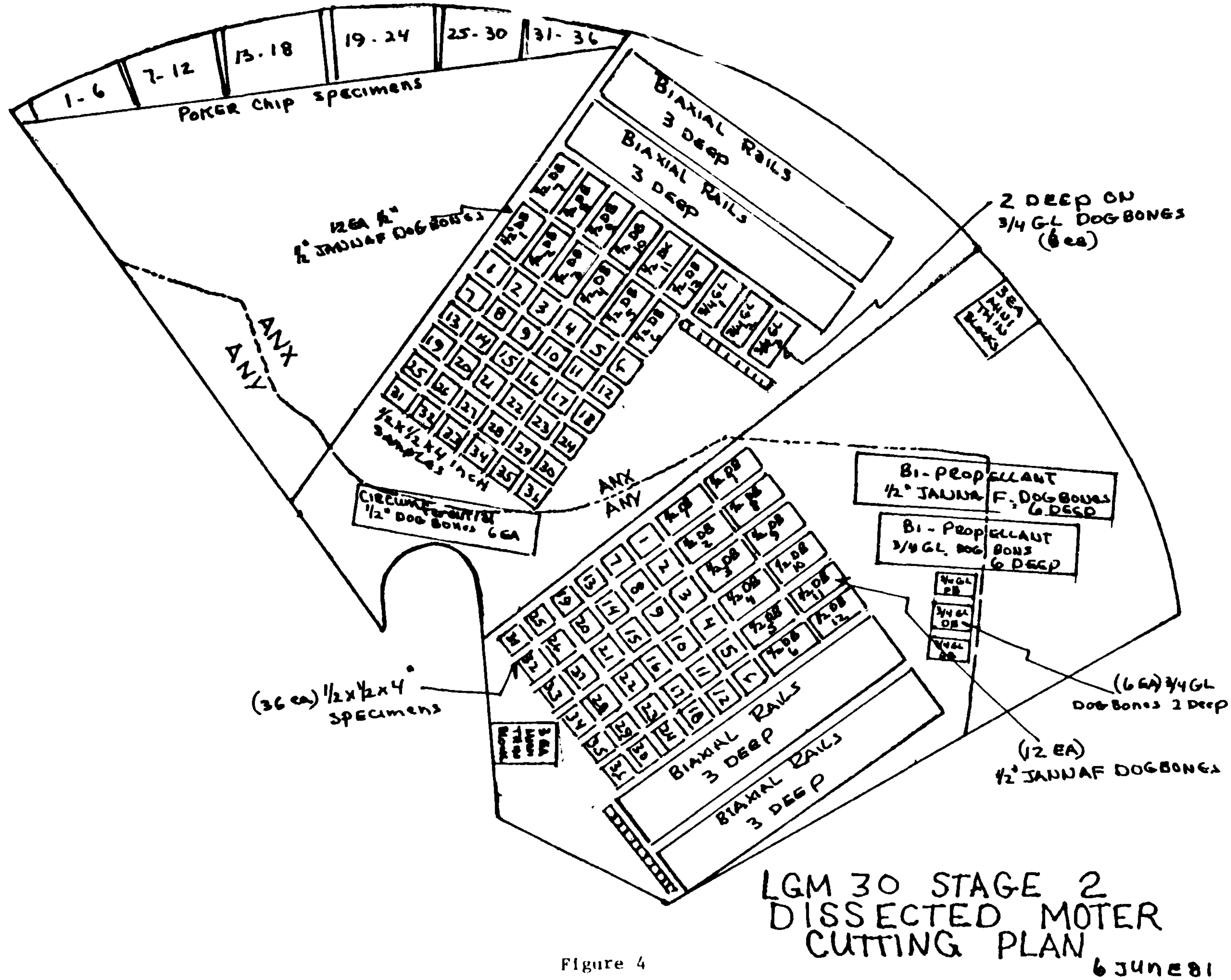
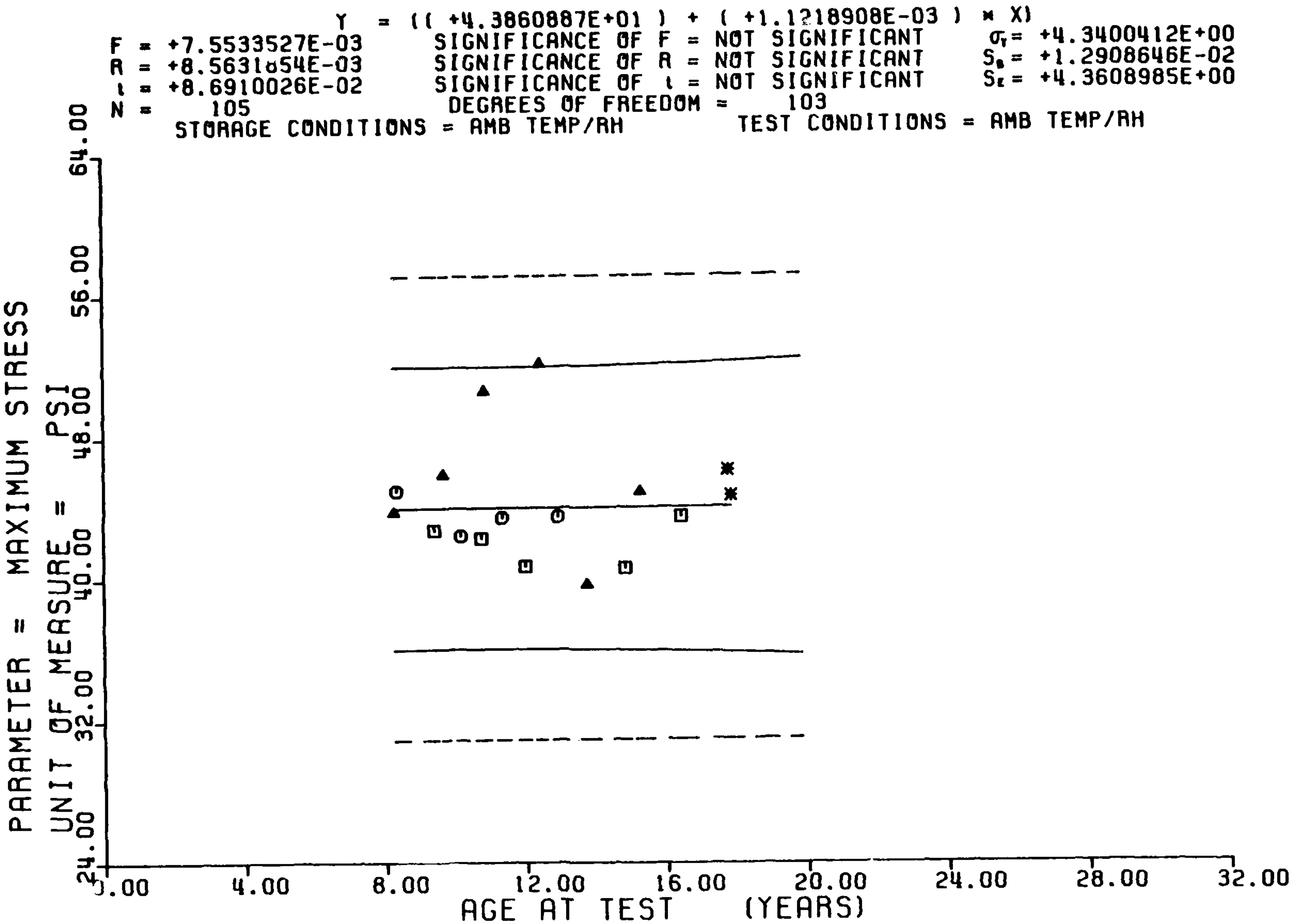


FIGURE 3



1-6
7-12
13-18
19-24
25-30
31-36
POKER CHIP SPECIMENS
BIAXIAL RAILS 3 DEEP
BIAXIAL RAILS 3 DEEP
12 EA 1/2" JANNAF DOG BONES
ANX
ANY
1/2 x 1/2 x 4 INCH SAMPLES
CIRCUMFERENTIAL 1/2" DOG BONES 6 EA
2 DEEP ON 3/4 GL DOG BONES (6 ea)
3 EA THIN BLOCKS
BI-PROPELLANT 1/2" JANNAF DOG BONES 6 DEEP
BI-PROPELLANT 3/4 GL DOG BONES 6 DEEP
(36 ea) 1/2 x 1/2 x 4" SPECIMENS
(6 EA) 3/4 GL DOG BONES 2 DEEP
(12 EA) 1/2" JANNAF DOGBONES
BIAXIAL RAILS 3 DEEP
BIAXIAL RAILS 3 DEEP
LGM 30 STAGE 2
DISSECTED MOTER
CUTTING PLAN
6 JUNE 81

Figure 4



II STAGE DSCT MTRS,OUTER,AXIAL POS,V.L.RATE CHS=0.0002 IN/MIN,MAXIMUM STRESS

Figure 5

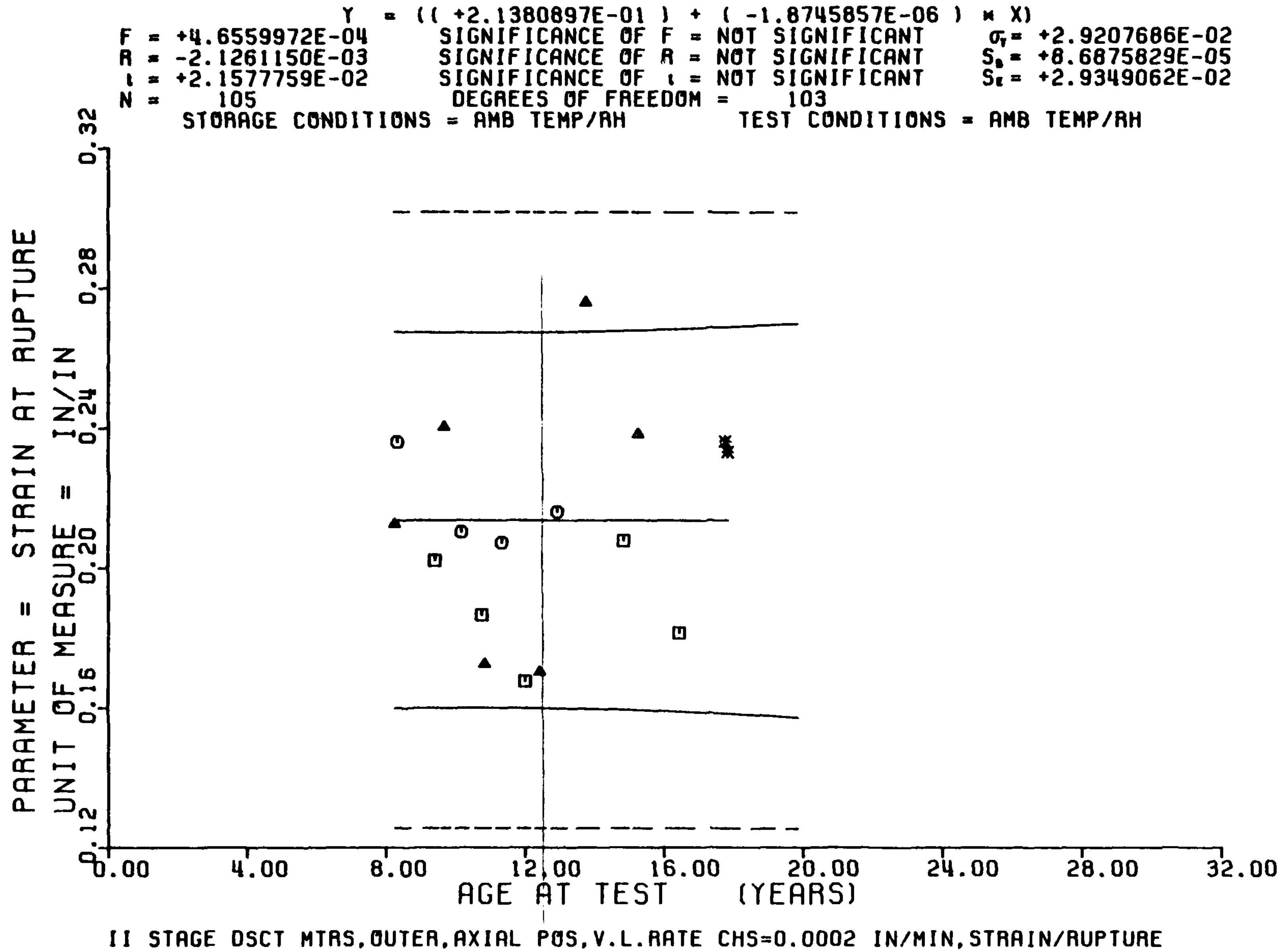

Y = ((+2.1380897E-01) + (-1.8745857E-06) * X)
F = +4.6559972E-04 SIGNIFICANCE OF F = NOT SIGNIFICANT σ = +2.9207686E-02
R = -2.1261150E-03 SIGNIFICANCE OF R = NOT SIGNIFICANT S = +8.6875829E-05
t = +2.1577759E-02 SIGNIFICANCE OF t = NOT SIGNIFICANT S = +2.9349062E-02
N = 105 DEGREES OF FREEDOM = 103
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = IN/IN
0.12
0.16
0.20
0.24
0.28
0.32
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCT MTRS,OUTER,AXIAL POS,V.L.RATE CHS=0.0002 IN/MIN,STRAIN/RUPTURE

Figure 6

Y = ((+3.4807983E+02) + (+4.9901388E-02) * X)

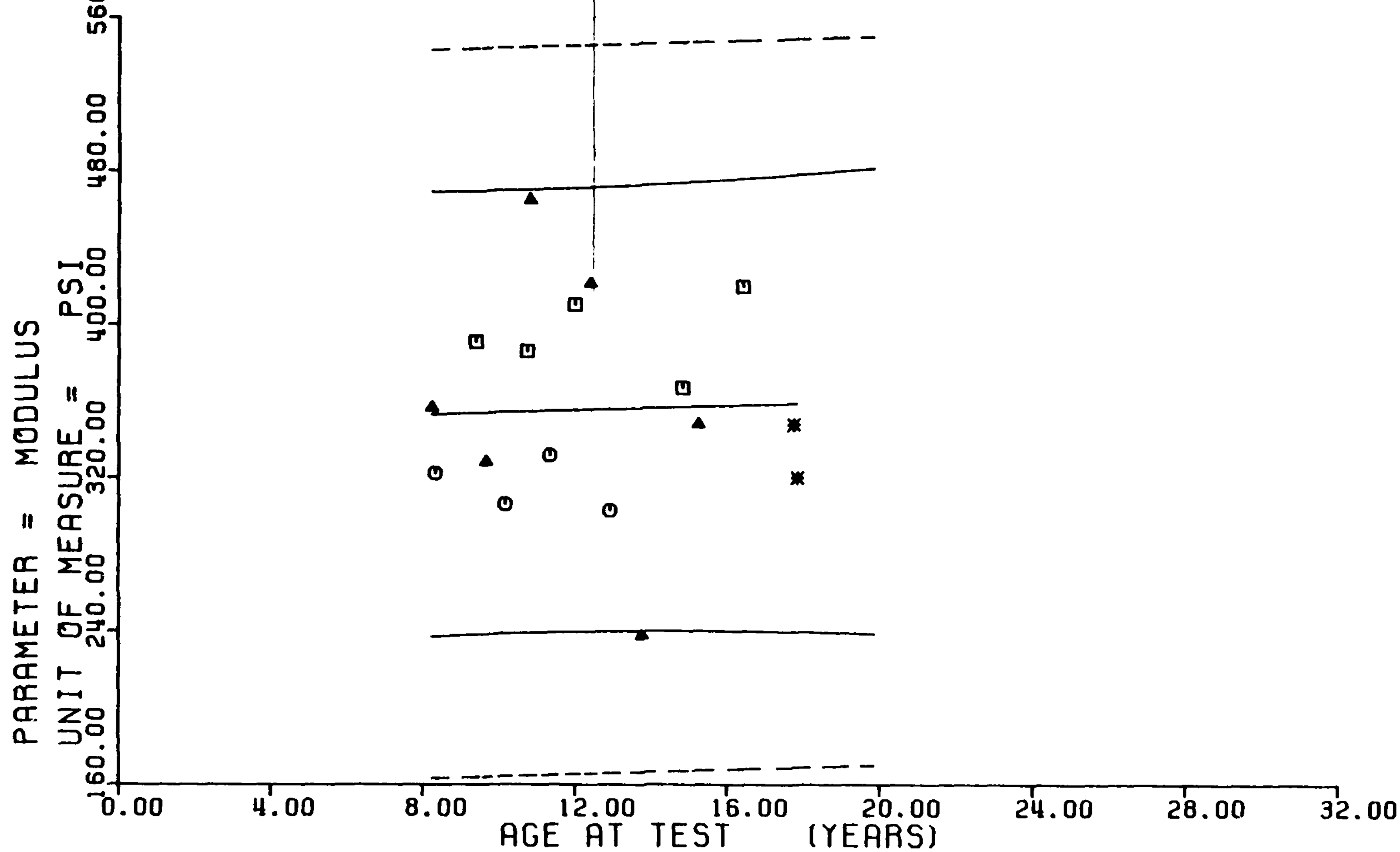
F = +7.0968023E-02 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +6.2998187E+01

R = +2.6239960E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +1.8731876E-01

t = +2.6639824E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_ϵ = +6.3281468E+01

N = 105 DEGREES OF FREEDOM = 103

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTRS,OUTER,AXIAL POS,V.L.RATE CHS=0.0002 IN/MIN, MODULUS

Figure 7

Y = ((+4.1977488E+01) + (+4.6565622E-02) * X)

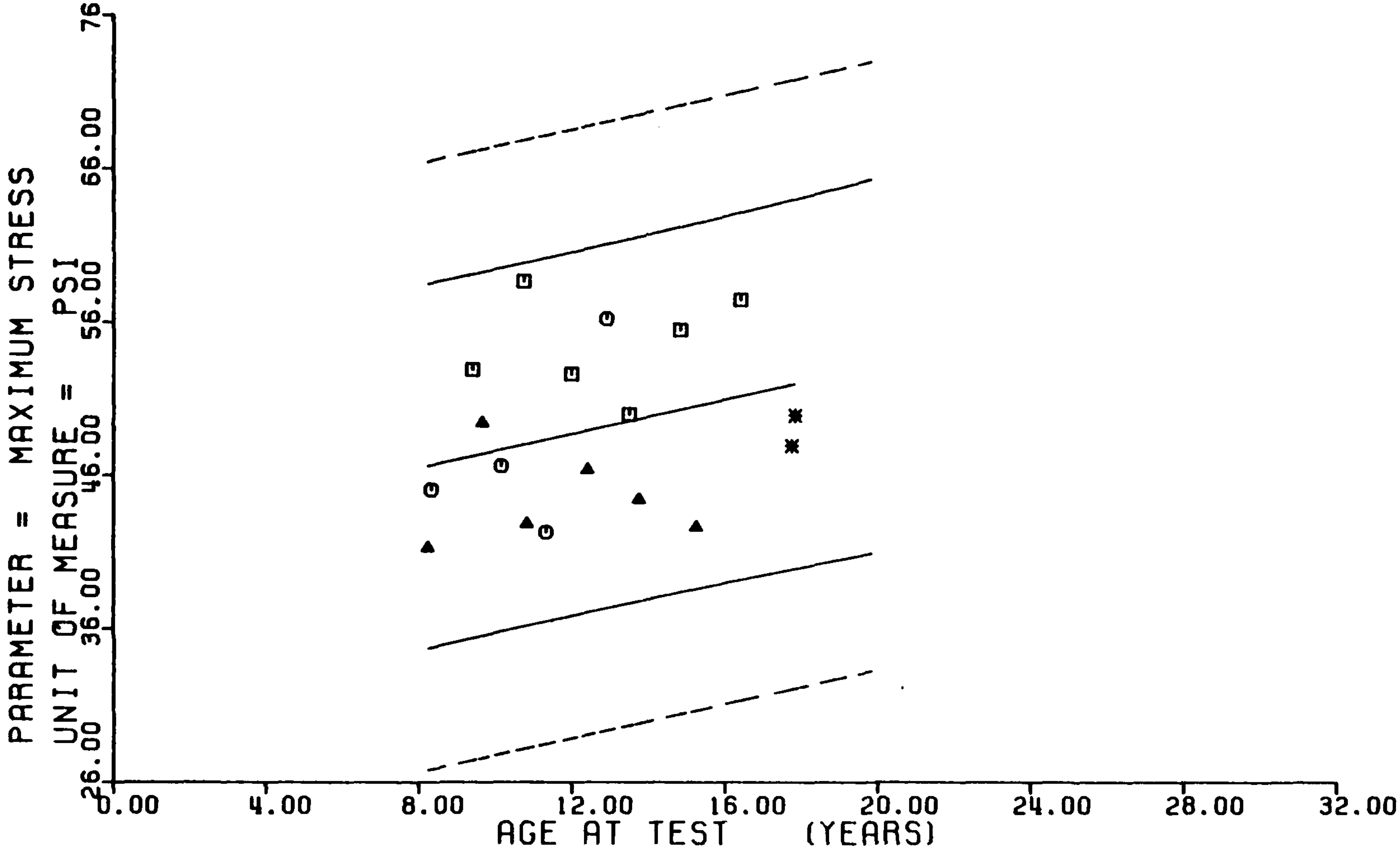
F = +9.5797061E+00 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +6.7967924E+00

R = +2.4814162E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +1.5044900E-02

ι = +3.0951100E+00 SIGNIFICANCE OF ι = SIGNIFICANT S_E = +6.6067245E+00

N = 148 DEGREES OF FREEDOM = 146

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTRS, INNER, AXIAL POS, V.L. RATE CHS=0.0002 IN/MIN, MAXIMUM STRESS

Figure 8

Y = ((+3.5567116E-01) + (-1.2313121E-04) * X)

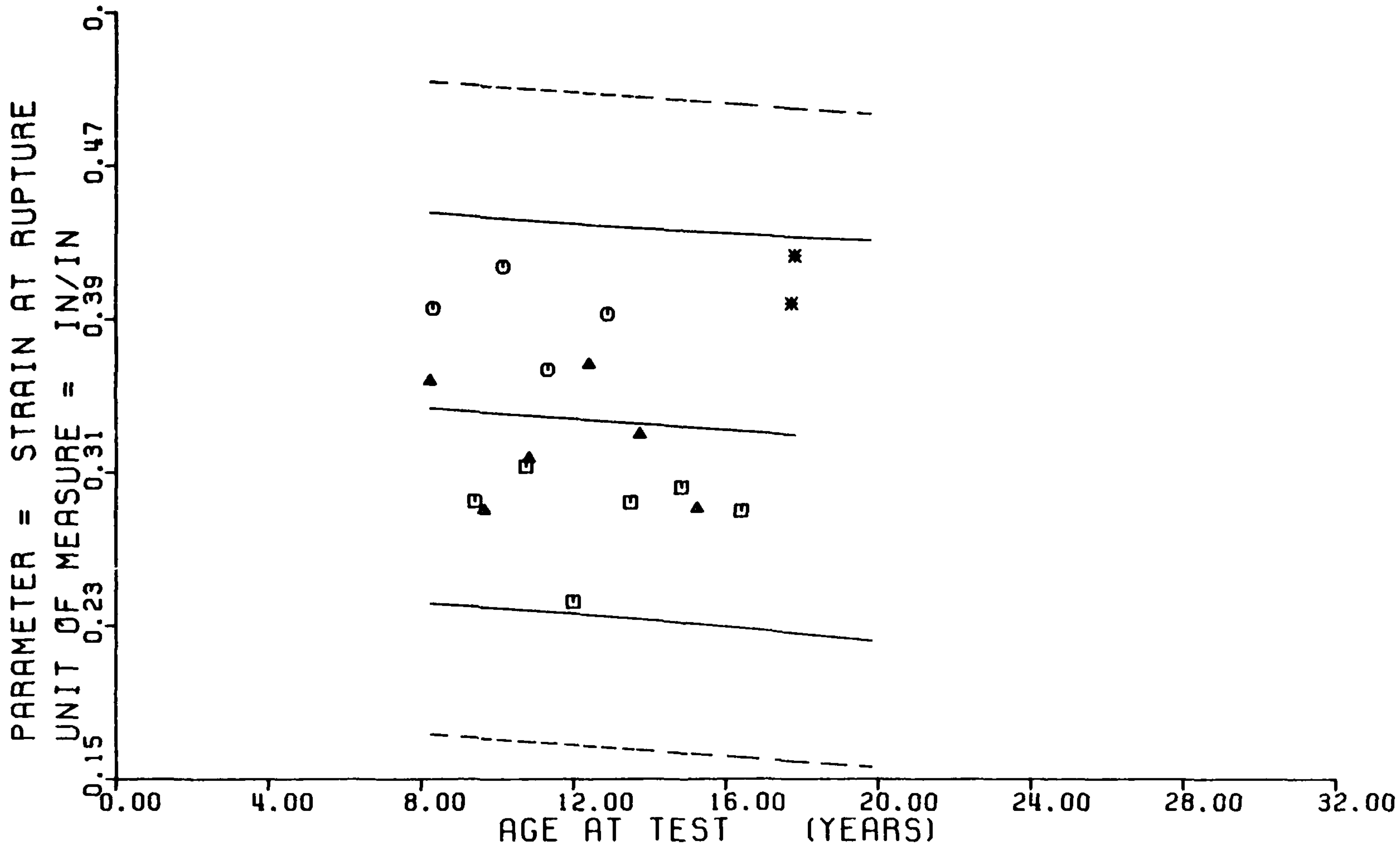
F = +9.0744828E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +5.6743660E-02

R = -7.8593935E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_b = +1.2925793E-04

t = +9.5260079E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +5.6761531E-02

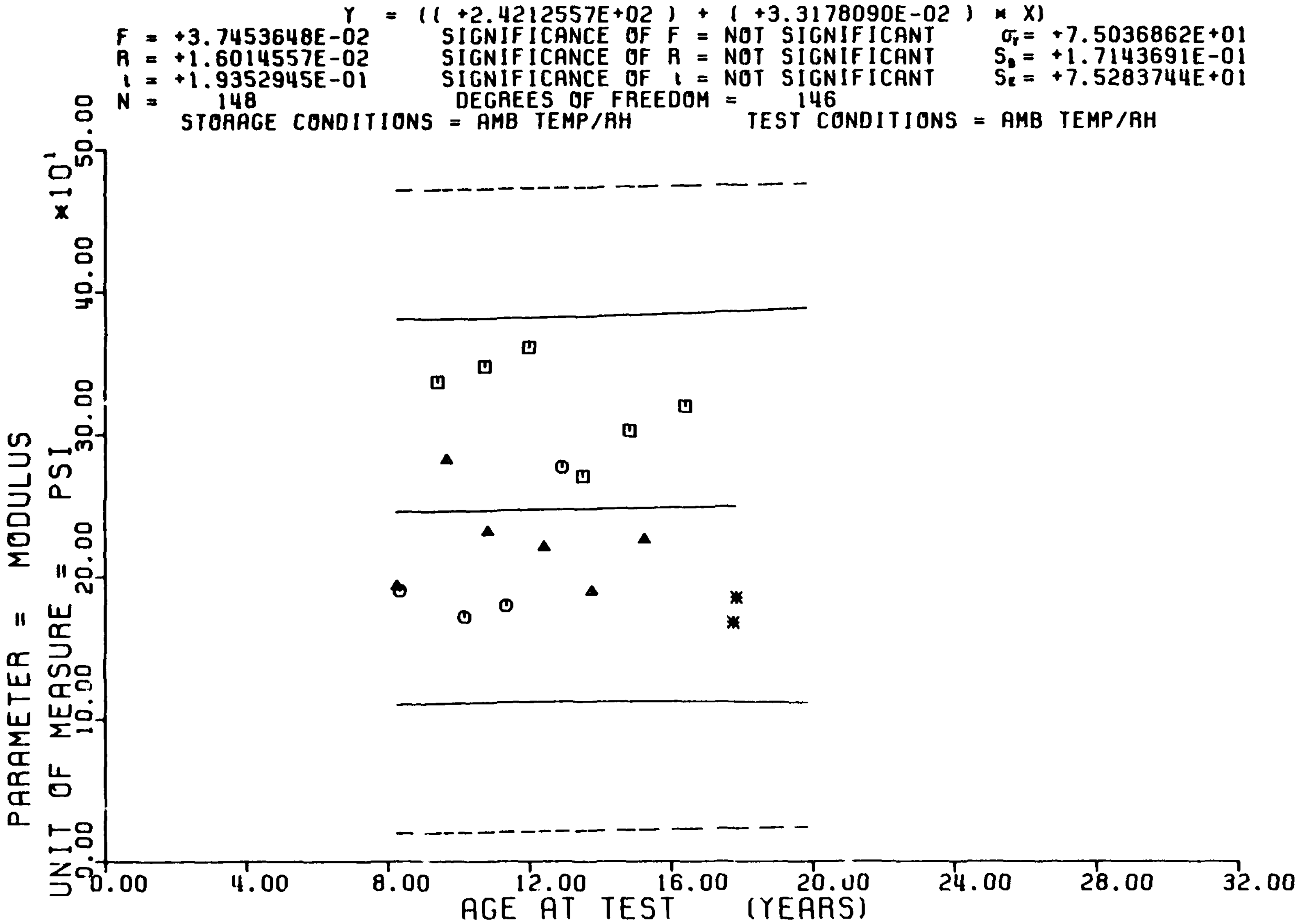
N = 148 DEGREES OF FREEDOM = 146

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTRS, INNER, AXIAL POS, V.L.RATE CHS=0.0002 IN/MIN, STRAIN/RUPTURE

Figure 9



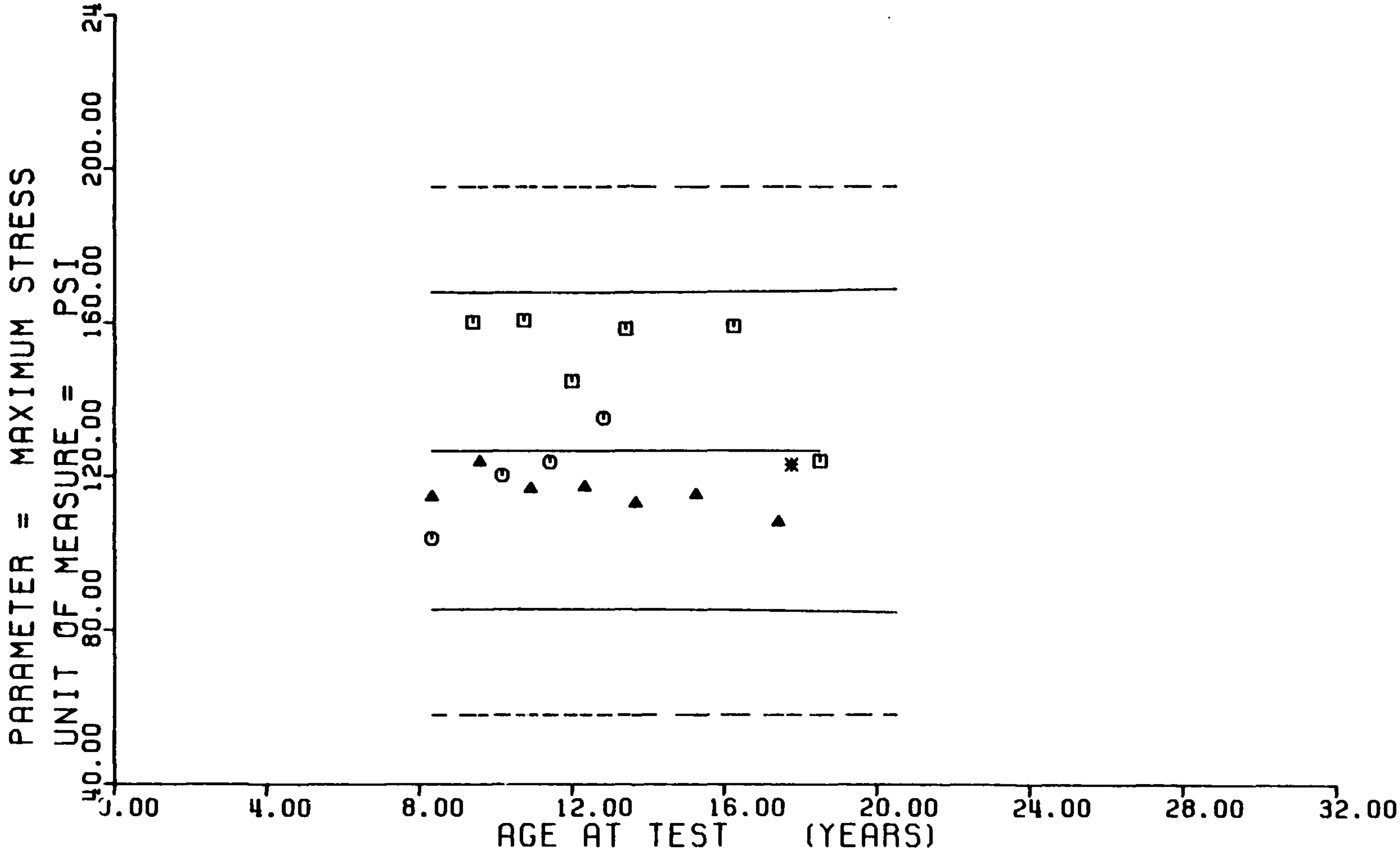
II STAGE DSCT MTRS, INNER, AXIAL POS, V.L.RATE CHS=0.0002 IN/MIN, MODULUS

Figure 10

Y = ((+1.2651806E+02) + (+8.6344404E-04) * X)

F = +3.8049802E-04 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +2.2798183E+01
R = +1.6726541E-03 SIGNIFICANCE OF R = NOT SIGNIFICANT S_β = +4.4264748E-02
ι = +1.9506358E-02 SIGNIFICANCE OF ι = NOT SIGNIFICANT S_E = +2.2881815E+01
N = 138 DEGREES OF FREEDOM = 136

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH

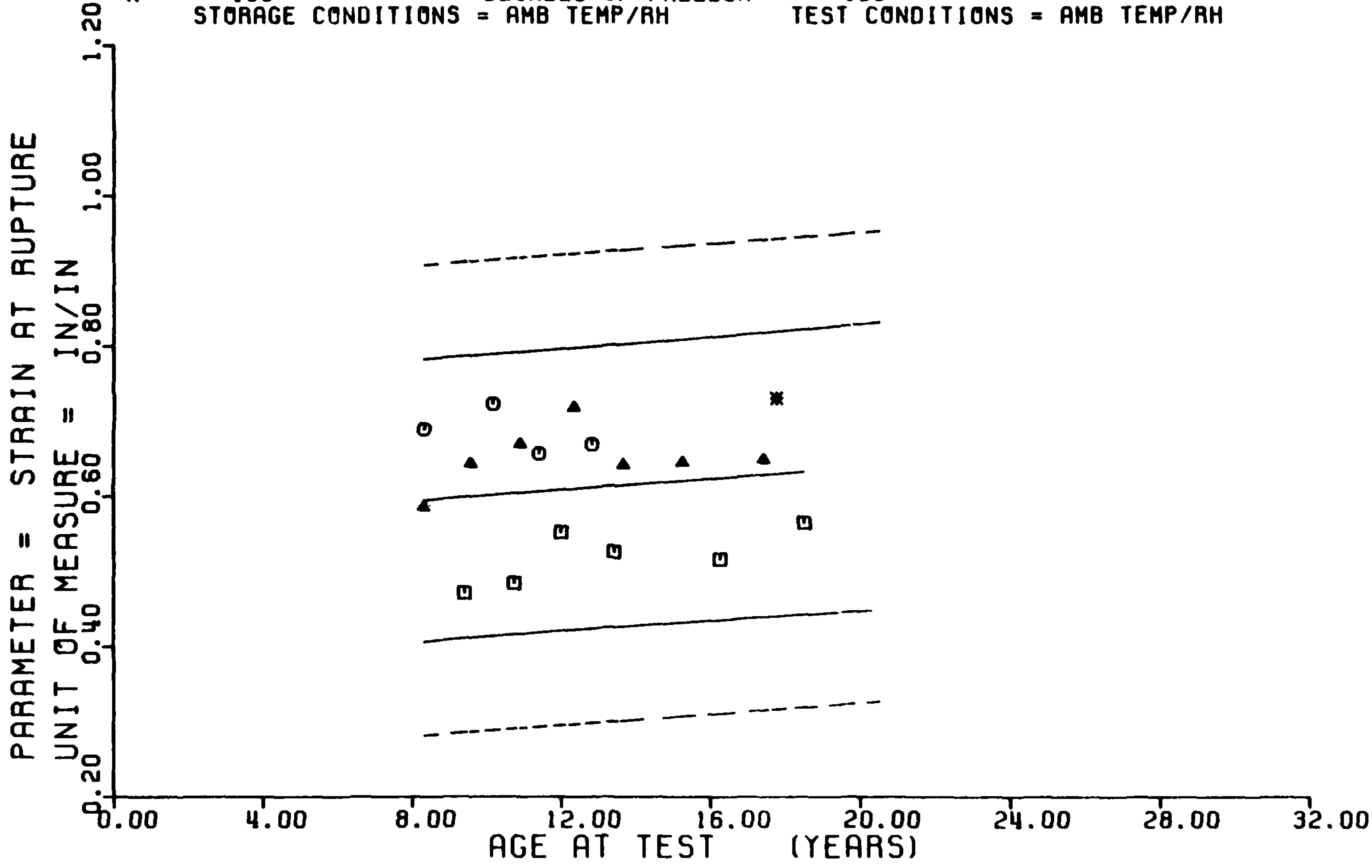


II STAGE,DSCT MTRS,ONLY, INNER,AXIAL POS.LOW RATE CHS=2.0 IN/MIN,MAX STRESS

Figure 11

$$Y = ((+5.6389454E-01) + (+3.0842893E-04) \times X)$$

F = +2.3347150E+00   SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +1.0485181E-01
R = +1.2991262E-01   SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +2.0185437E-04
t = +1.5279774E+00   SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +1.0434475E-01
N = 138   DEGREES OF FREEDOM = 136
STORAGE CONDITIONS = AMB TEMP/RH   TEST CONDITIONS = AMB TEMP/RH



II STAGE,DSCT MTRS,ONLY, INNER,AXIAL POS.LOW RATE CHS=2.0 IN/MIN,STRAIN/RUPTURE

Figure 12

Y = ((+7.4695687E+02) + (+3.2324252E-01) * X)

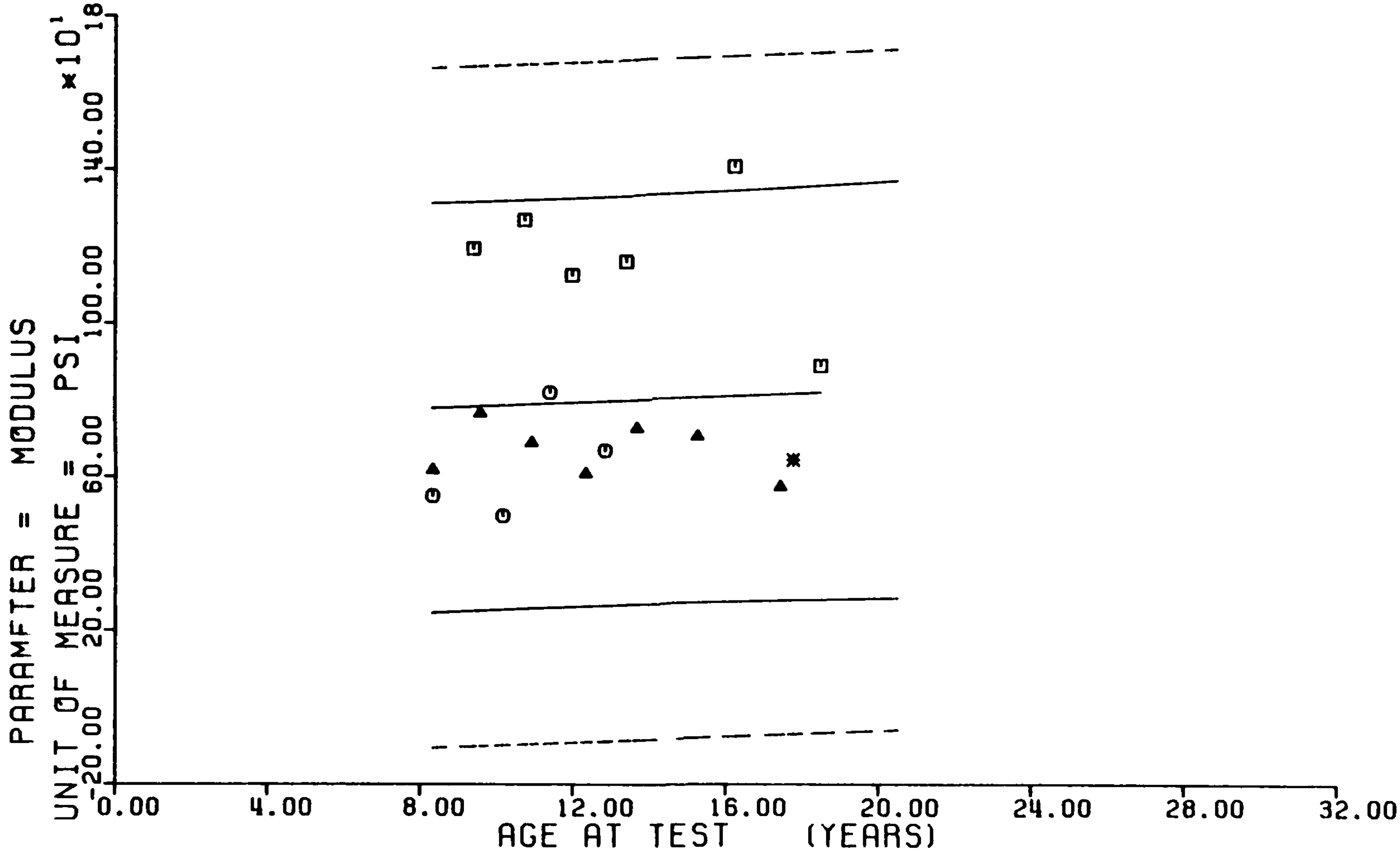
F = +3.1307441E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +2.9422926E+02

R = +4.9015088E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +5.7770309E-01

t = +5.5953053E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +2.9500374E+02

N = 132 DEGREES OF FREEDOM = 130

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE,DSCT MTRS,ONLY, INNER,AXIAL POS.LOW RATE CHS=2.0 IN/MIN, MODULUS

Figure 13

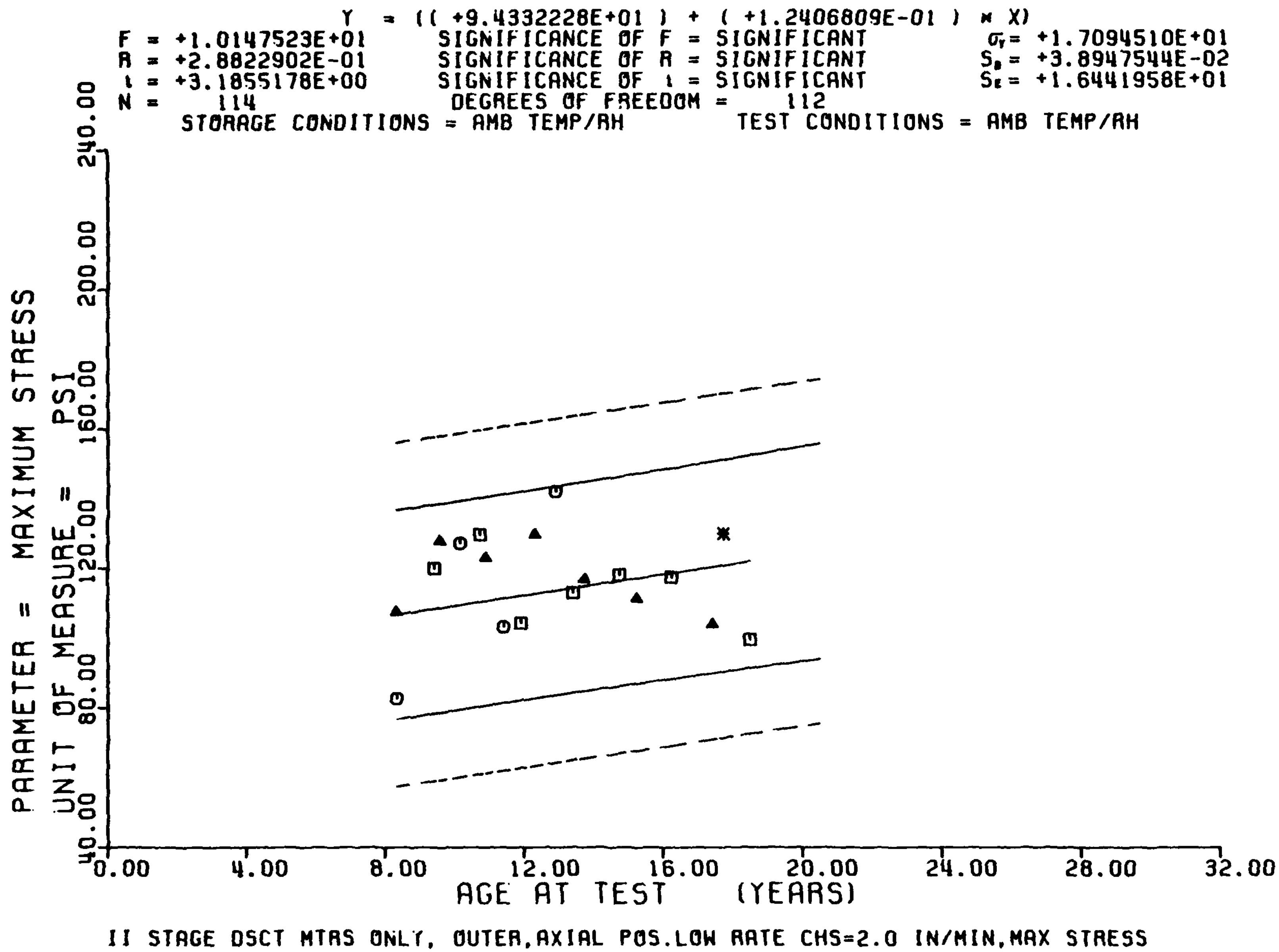
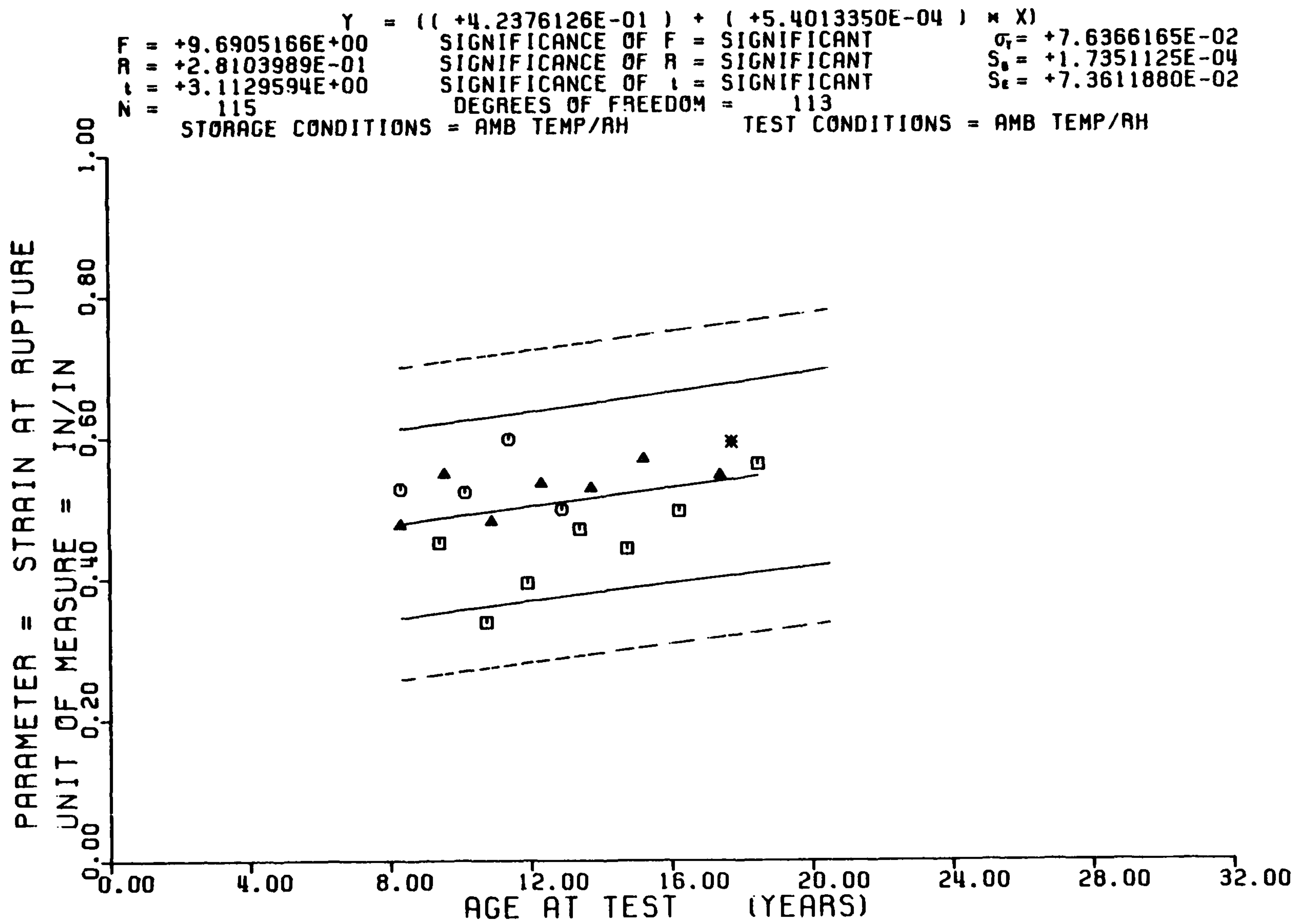

Y = ((+9.4332228E+01) + (+1.2406809E-01) * X)
F = +1.0147523E+01 SIGNIFICANCE OF F = SIGNIFICANT σ = +1.7094510E+01
R = +2.8822902E-01 SIGNIFICANCE OF R = SIGNIFICANT S = +3.8947544E-02
t = +3.1855178E+00 SIGNIFICANCE OF t = SIGNIFICANT S = +1.6441958E+01
N = 114 DEGREES OF FREEDOM = 112
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
240.00
200.00
160.00
120.00
80.00
40.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCT MTRS ONLY, OUTER,AXIAL POS.LOW RATE CHS=2.0 IN/MIN,MAX STRESS

Figure 14

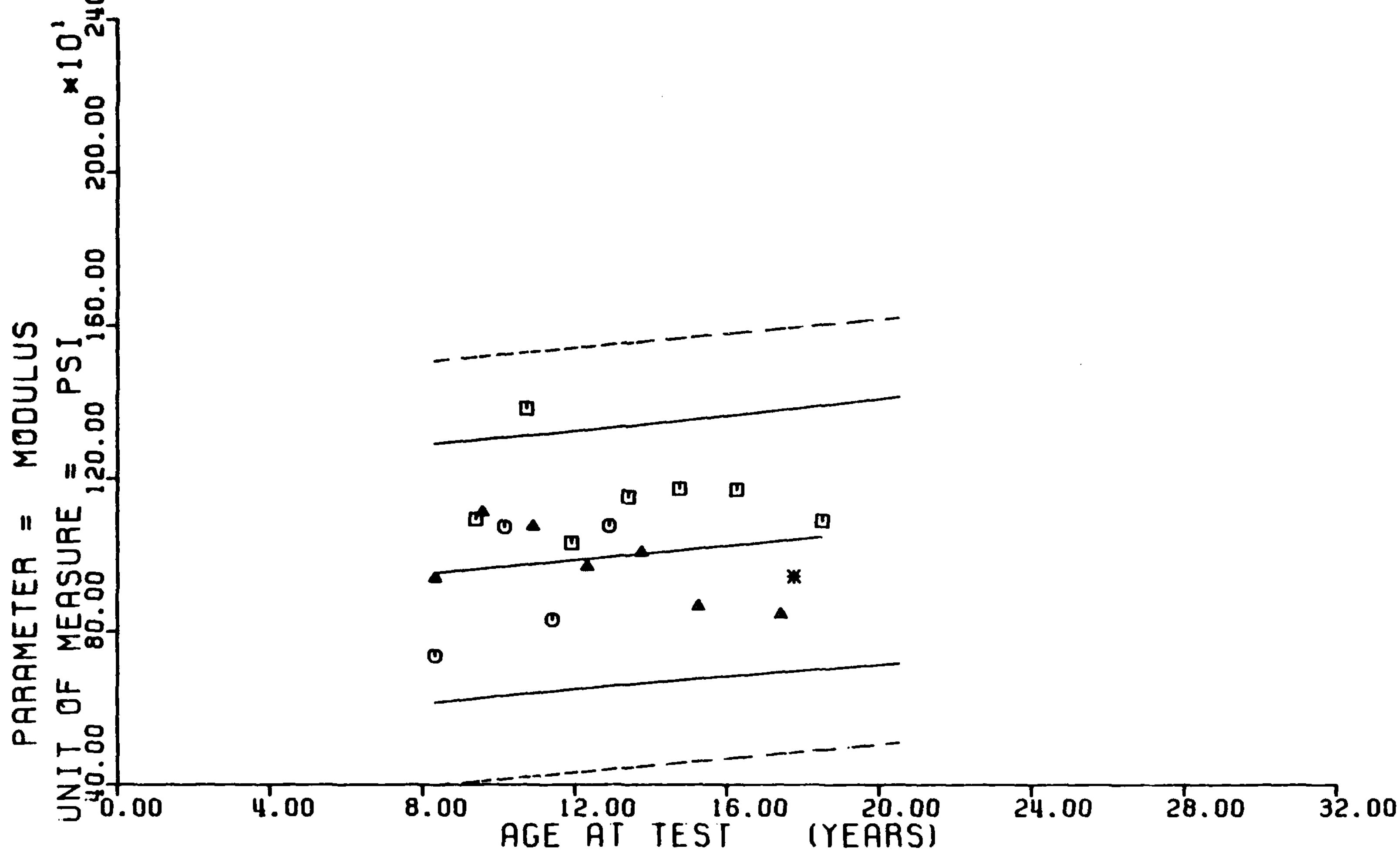


II STAGE OSCT MTRS ONLY, OUTER,AXIAL POS.LOW RATE CHS=2.0 IN/MIN,STRAIN/RUPTURE

Figure 15

Y = ((+8.7649516E+02) + (+7.6460111E-01) * X)

F = +2.9833206E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +1.8663844E+02
R = +1.6469732E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +4.4267495E-01
t = +1.7272291E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +1.8494796E+02
N = 109 DEGREES OF FREEDOM = 107
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE OSCT MTRS ONLY, OUTER,AXIAL POS.LOW RATE CHS=2.0 IN/MIN, MODULUS

Figure 16

Y = ((+1.1573136E+02) + (-1.0156211E-01) * X)

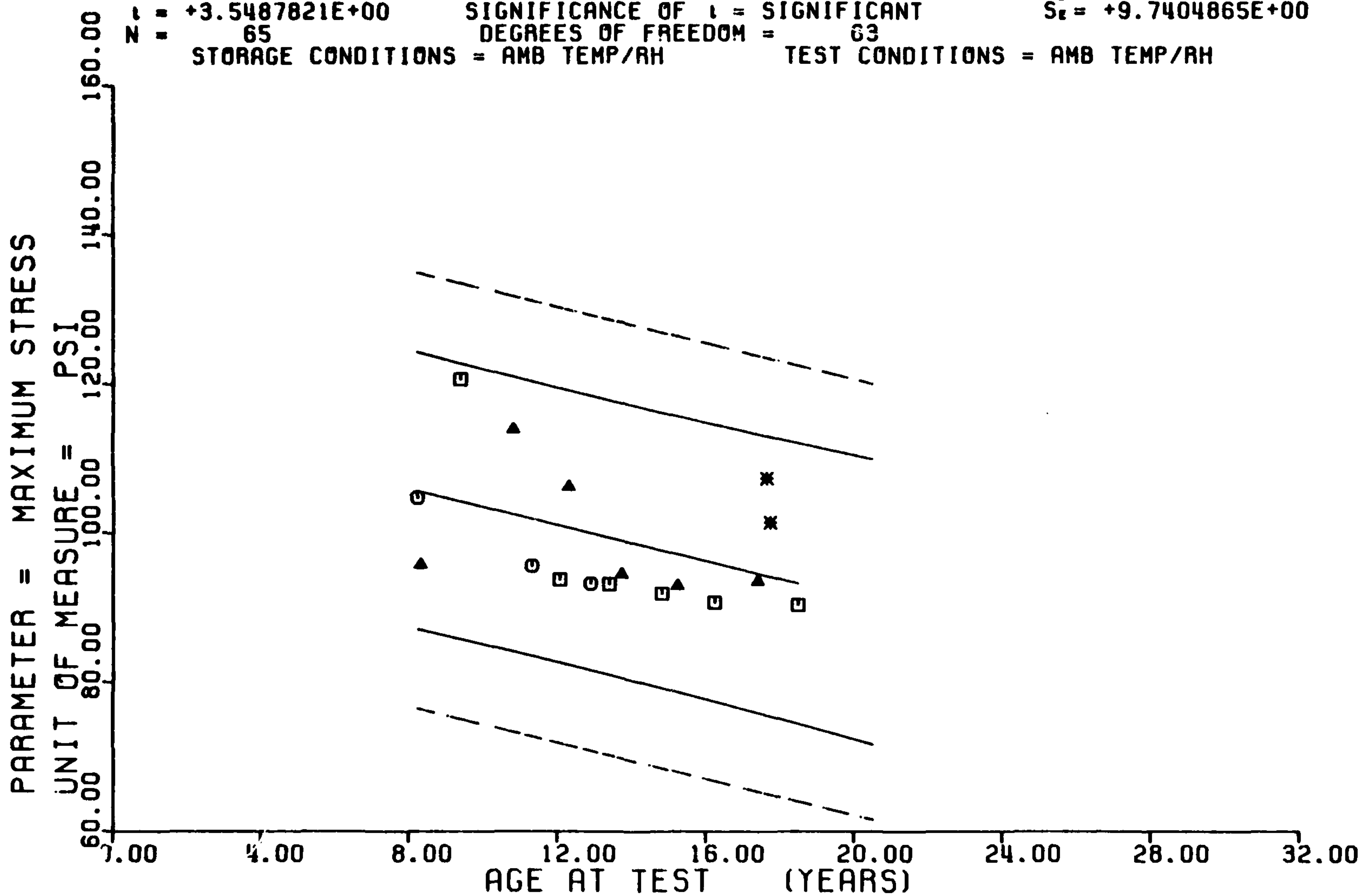
F = +1.2593854E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_T = +1.0586049E+01

R = -4.0816531E-01 SIGNIFICANCE OF R = SIGNIFICANT S_b = +2.8618865E-02

t = +3.5487821E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +9.7404865E+00

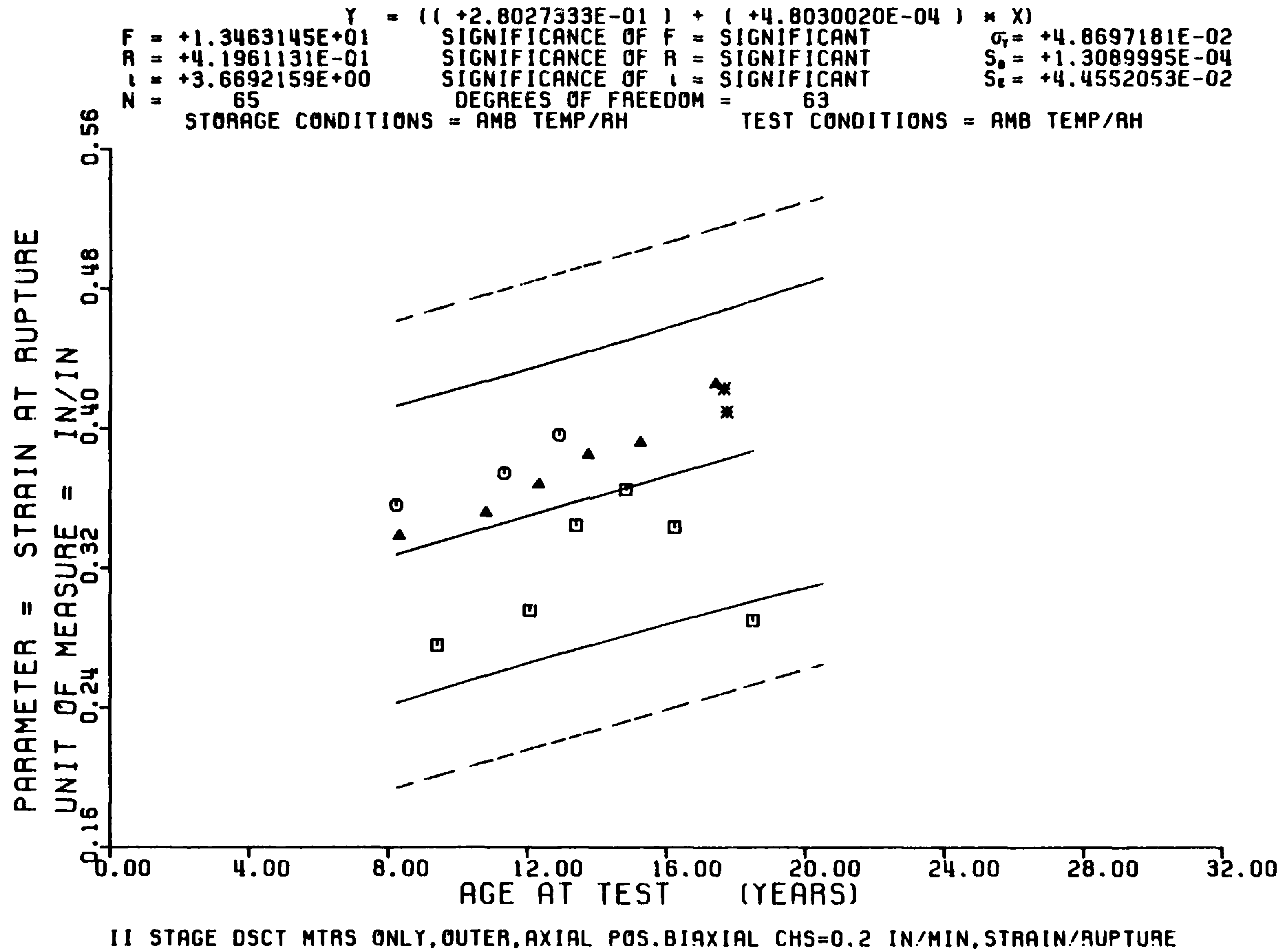
N = 65 DEGREES OF FREEDOM = 63

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



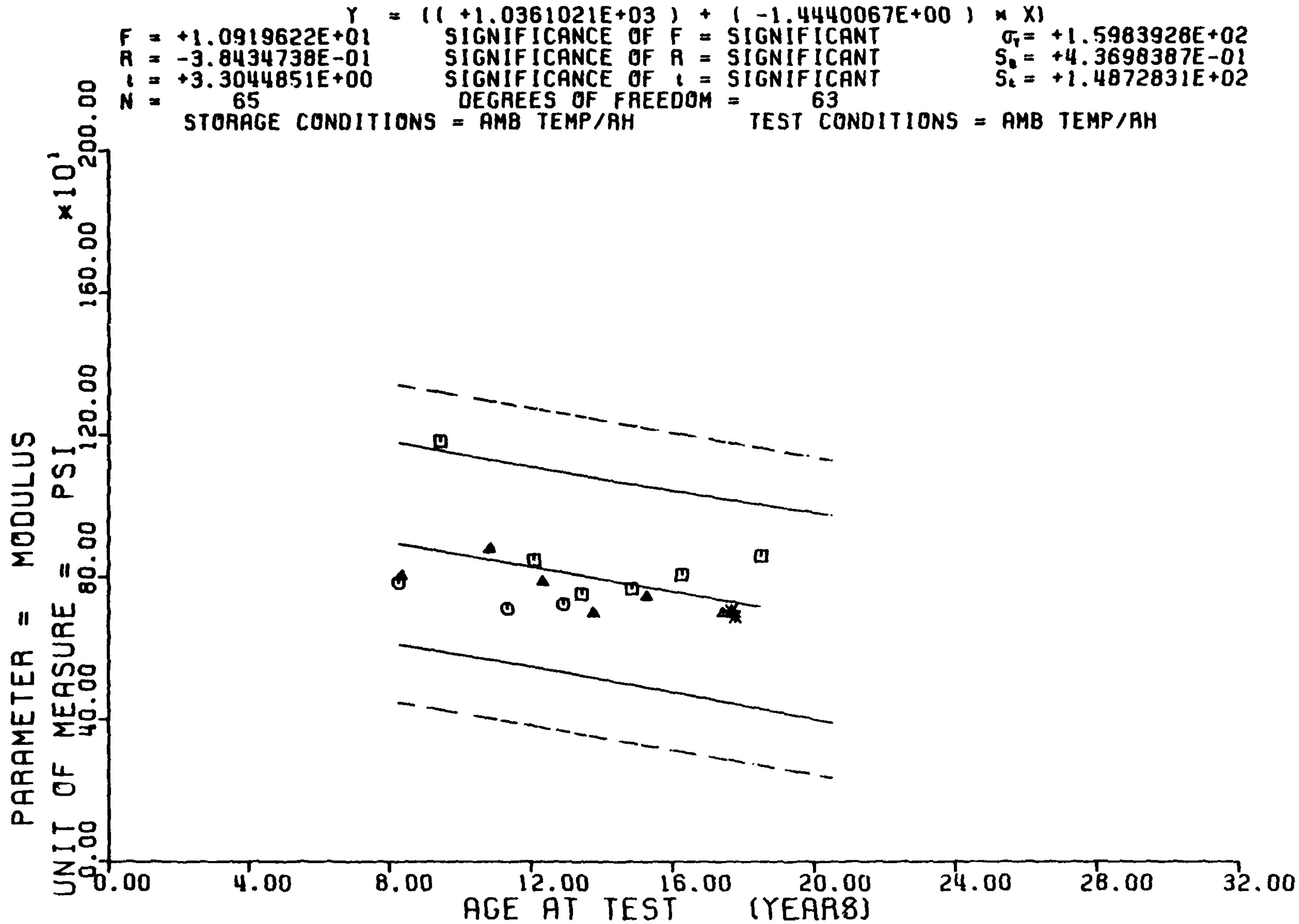
II STAGE DSCT MTRS ONLY,OUTER,AXIAL POS.BIAXIAL CHS=0.2 IN/MIN,MAXIMUM STRESS

Figure 17



Y = ((+2.8027333E-01) + (+4.8030020E-04) * X)
F = +1.3463145E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_T = +4.8697181E-02
R = +4.1961131E-01 SIGNIFICANCE OF R = SIGNIFICANT S_b = +1.3089995E-04
ι = +3.6692159E+00 SIGNIFICANCE OF ι = SIGNIFICANT S_ϵ = +4.4552053E-02
N = 65 DEGREES OF FREEDOM = 63
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = IN/IN
0.16
0.24
0.32
0.40
0.48
0.56
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCT MTRS ONLY,OUTER,AXIAL POS.BIAXIAL CHS=0.2 IN/MIN,STRAIN/RUPTURE

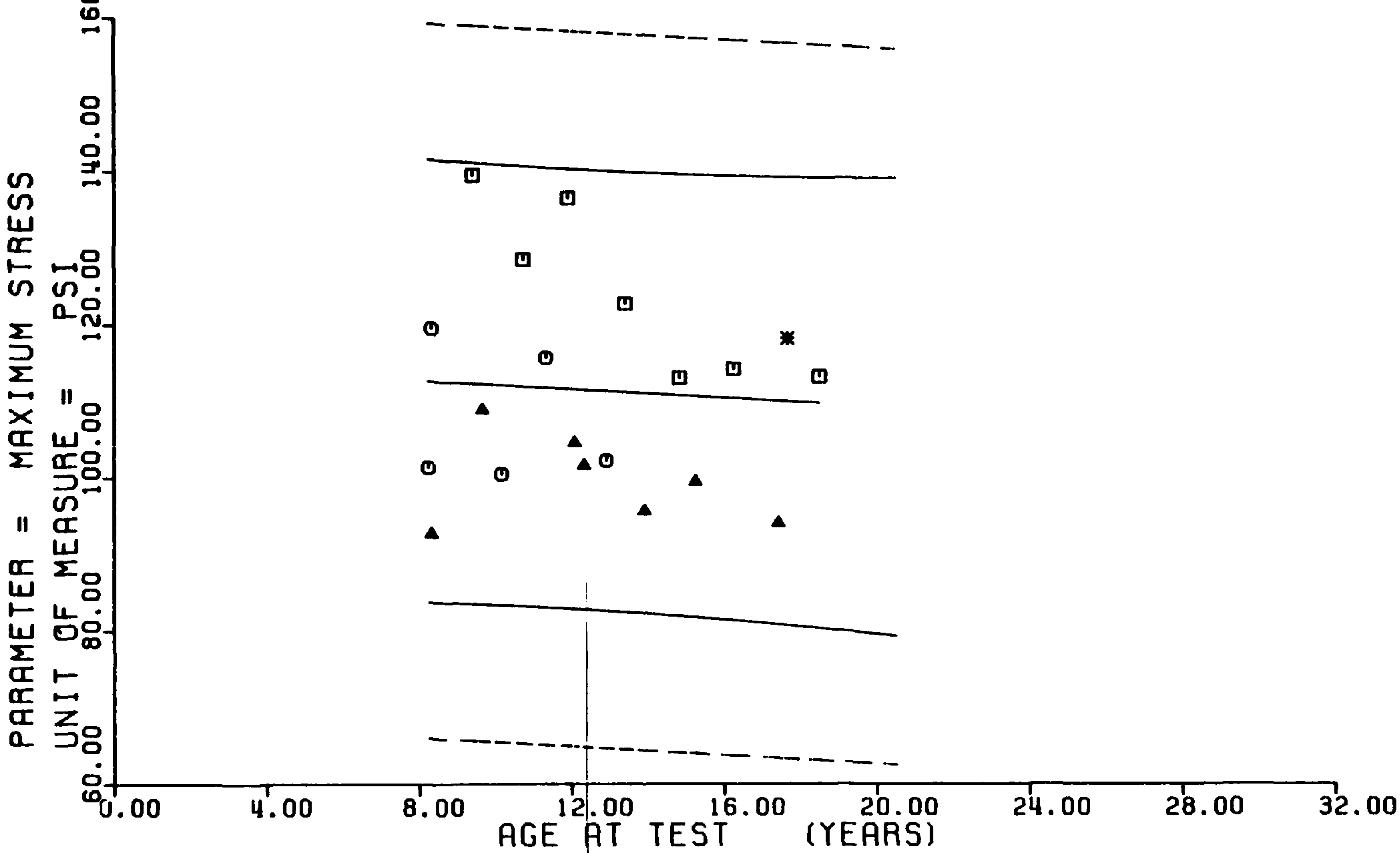
Figure 18



II STAGE DSCT MTRS ONLY,OUTER,AXIAL POS.BIAXIAL CHS=0.2 IN/MIN, MODULUS

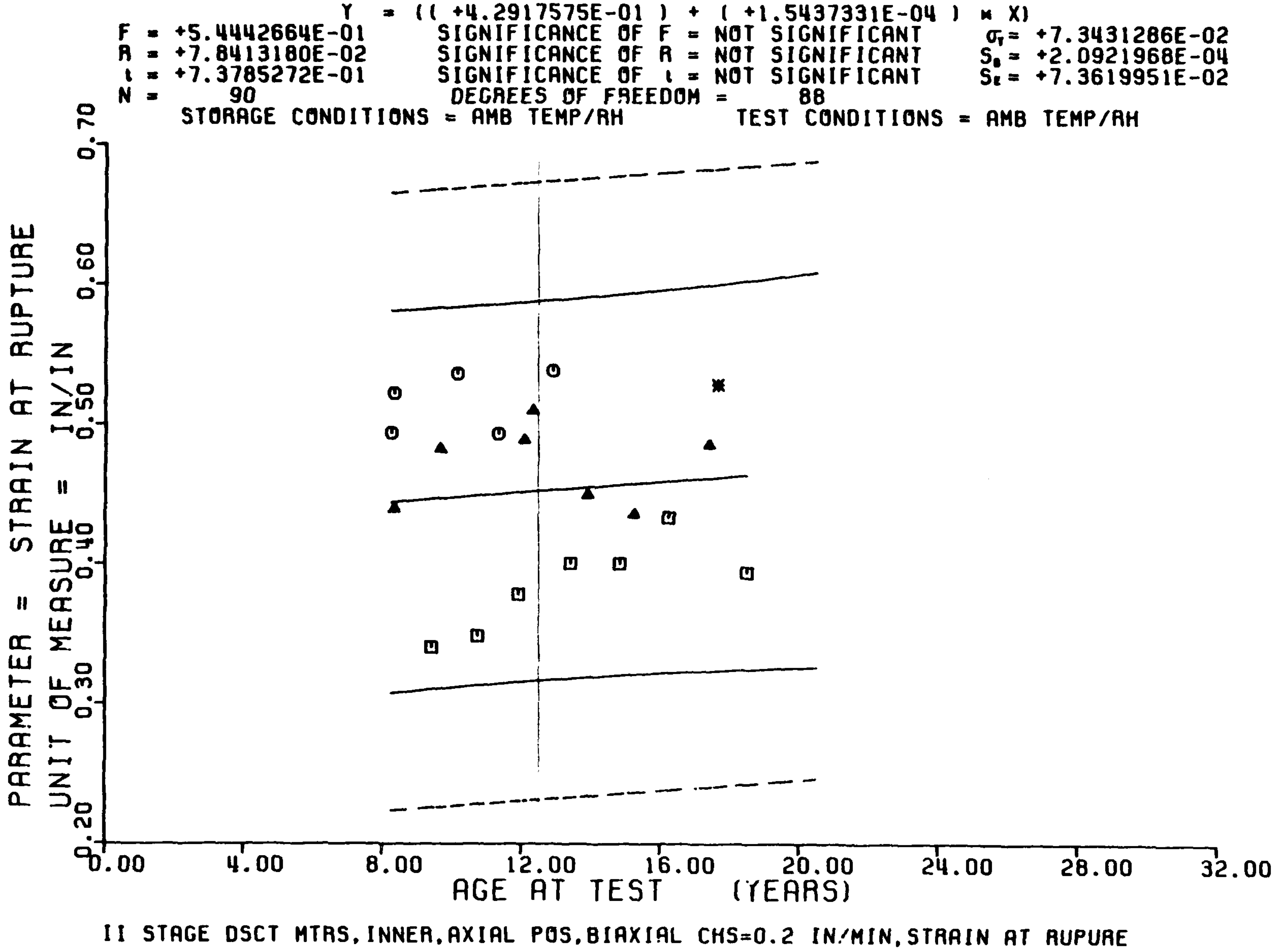
Figure 19

Y = ((+1.1494409E+02) + (-2.3808016E-02) * X)
F = +2.9072796E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +1.5475166E+01
R = -5.7383344E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +4.4154991E-02
t = +5.3919195E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +1.5537201E+01
N = 90 DEGREES OF FREEDOM = 88
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



STAGE II DISSECTED MTAS, INNER, AXIAL POS. BIAXIAL CHS=0.2 IN/MIN, MAX STRESS

Figure 20



Y = ((+4.2917575E-01) + (+1.5437331E-04) * X)
F = +5.4442664E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σT = +7.3431286E-02
R = +7.8413180E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT SB = +2.0921968E-04
t = +7.3785272E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT SE = +7.3619951E-02
N = 90 DEGREES OF FREEDOM = 88
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = IN/IN
0.20
0.30
0.40
0.50
0.60
0.70
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCT MTRS, INNER, AXIAL POS, BIAXIAL CHS=0.2 IN/MIN, STRAIN AT RUPURE

Figure 21

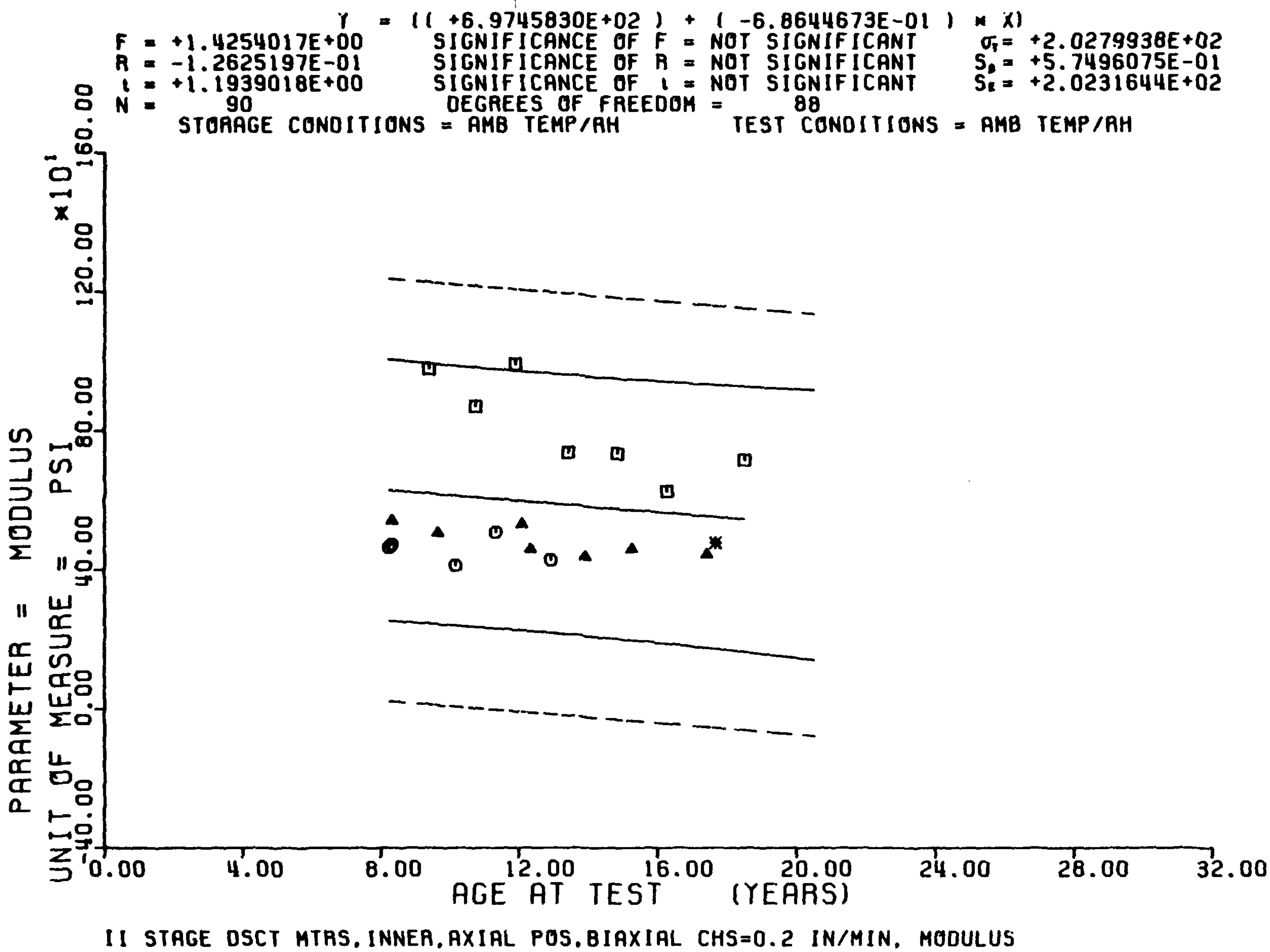

Y = ((+6.9745830E+02) + (-6.8644673E-01) * X)
F = +1.4254017E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ = +2.0279938E+02
R = -1.2625197E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S = +5.7496075E-01
t = +1.1939018E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S = +2.0231644E+02
N = 90 DEGREES OF FREEDOM = 88
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
PARAMETER = MODULUS
UNIT OF MEASURE = PSI
*10^1
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCT MTRS, INNER, AXIAL POS, BIAXIAL CHS=0.2 IN/MIN, MODULUS

Figure 22

Y = ((+1.9636572E+02) + (+1.7661540E+00) * X)

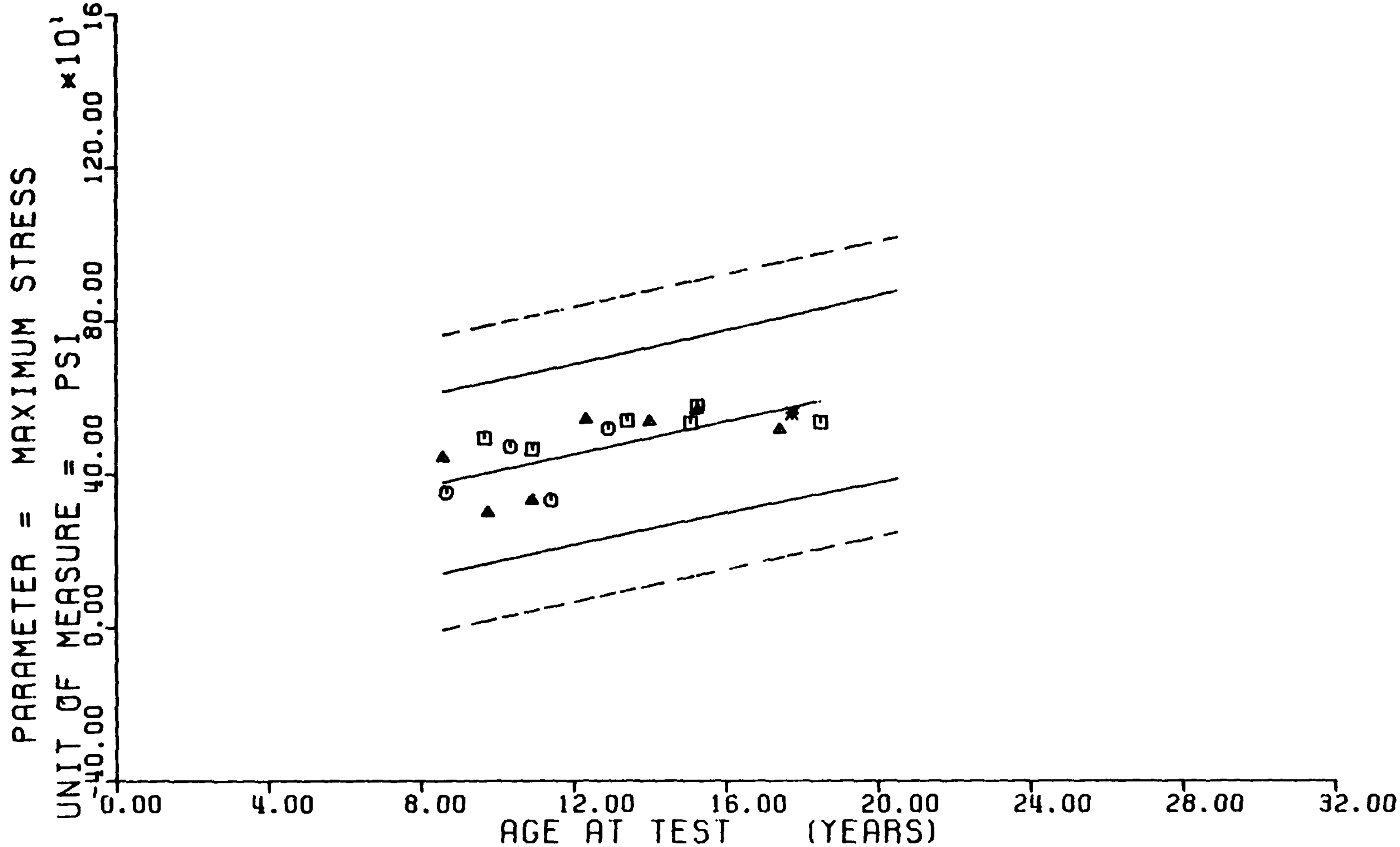
F = +2.4050696E+01   SIGNIFICANCE OF F = SIGNIFICANT σ_T = +1.4296063E+02

R = +4.5329071E-01   SIGNIFICANCE OF R = SIGNIFICANT S_B = +3.6013451E-01

ι = +4.9041509E+00   SIGNIFICANCE OF ι = SIGNIFICANT S_E = +1.2811306E+02

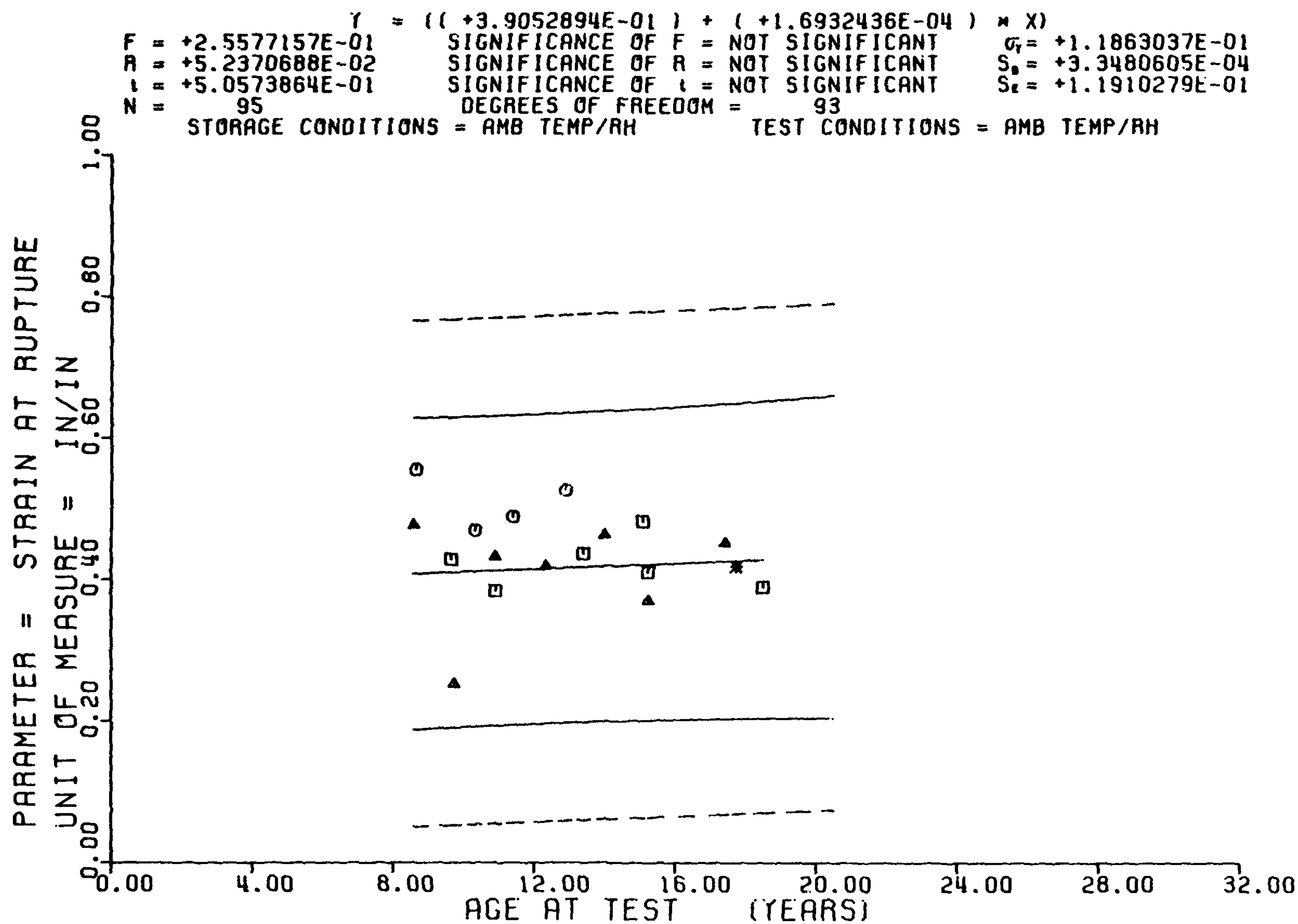
N = 95   DEGREES OF FREEDOM = 93

STORAGE CONDITIONS = AMB TEMP/RH   TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTRS,OUTER,AXIAL,H.R.HYDRO.CHS=1750 AT 500 PSI,MAXIMUM STRESS

Figure 23



II STAGE DSCT MTRS,OUTER,AXIAL,H.R.HYDRO.CHS=1750 AT 500 PSI,STRAIN/RUPTURE

Figure 24

Y = ((-1.8984390E+02) + (+3.3981604E+01) * X)

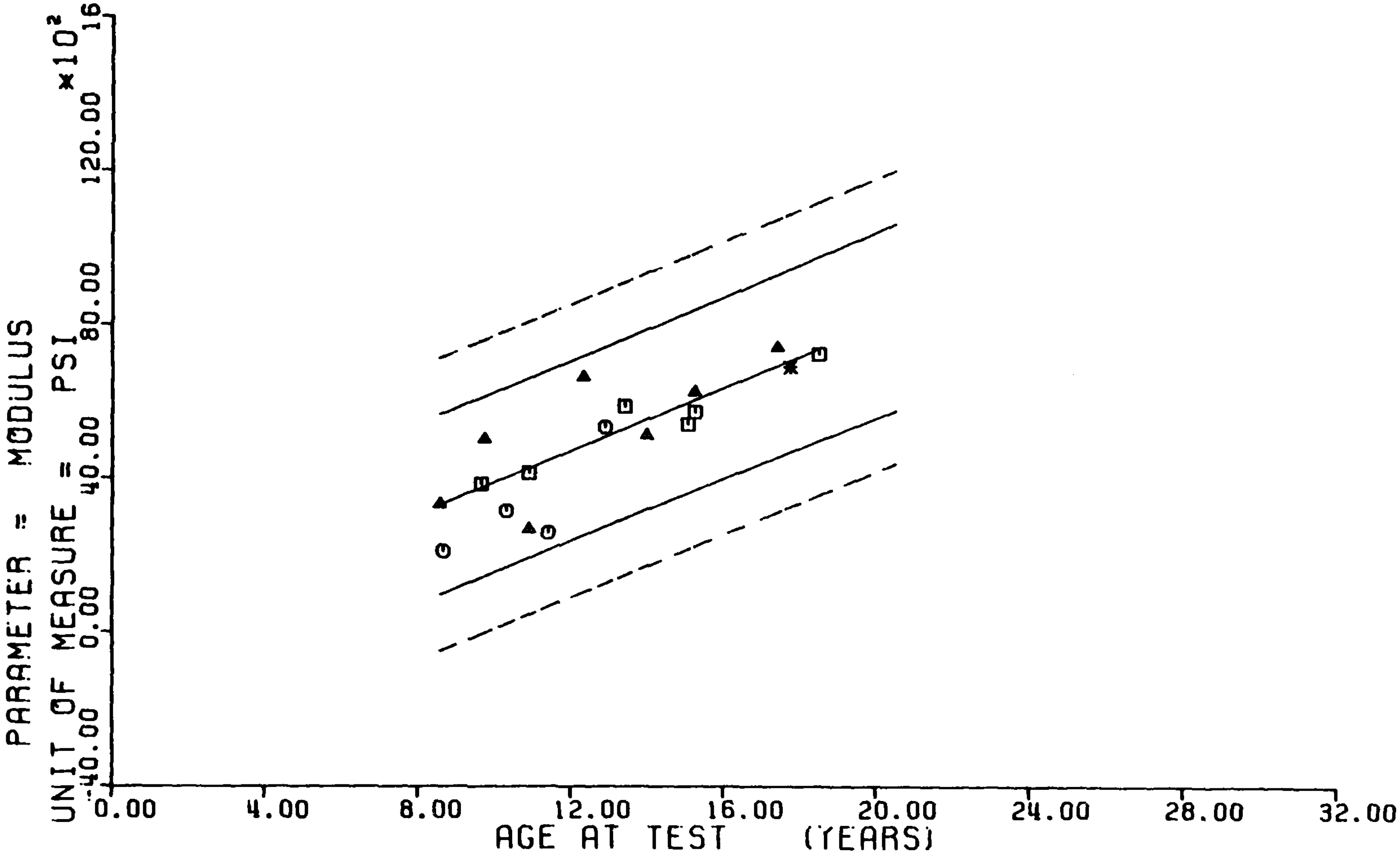
F = +9.0991458E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +1.7729934E+03

R = +7.0323662E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +3.5624073E+00

t = +9.5389443E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +1.2672789E+03

N = 95 DEGREES OF FREEDOM = 93

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE OSCT MTRS,OUTER,AXIAL,H.R.HYDRO.CHS=1750 AT 500 PSI, MODULUS

Figure 25

Y = ((+3.5321611E+02) + (+1.0537739E+00) * X)

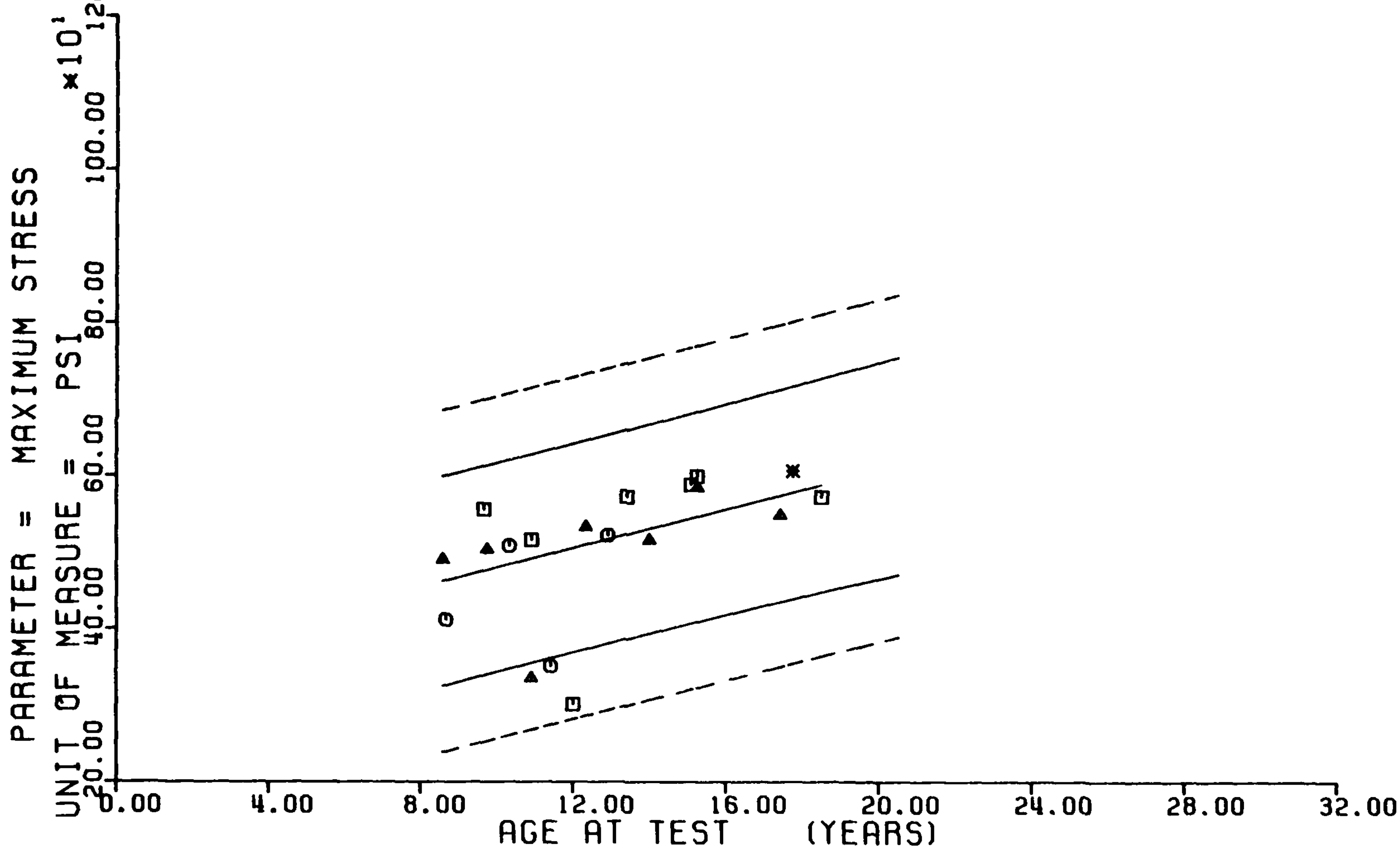
F = +2.4734381E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +8.2615027E+01

R = +4.4353051E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +2.1188339E-01

t = +4.9733671E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +7.4410138E+01

N = 103 DEGREES OF FREEDOM = 101

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTRS, INNER, AXIAL, H.R. HYDRO. CHS=1750 AT 500 PSI, MAXIMUM STRESS

Figure 26

Y = ((+6.9243870E-01) + (-6.1102017E-04) * X)

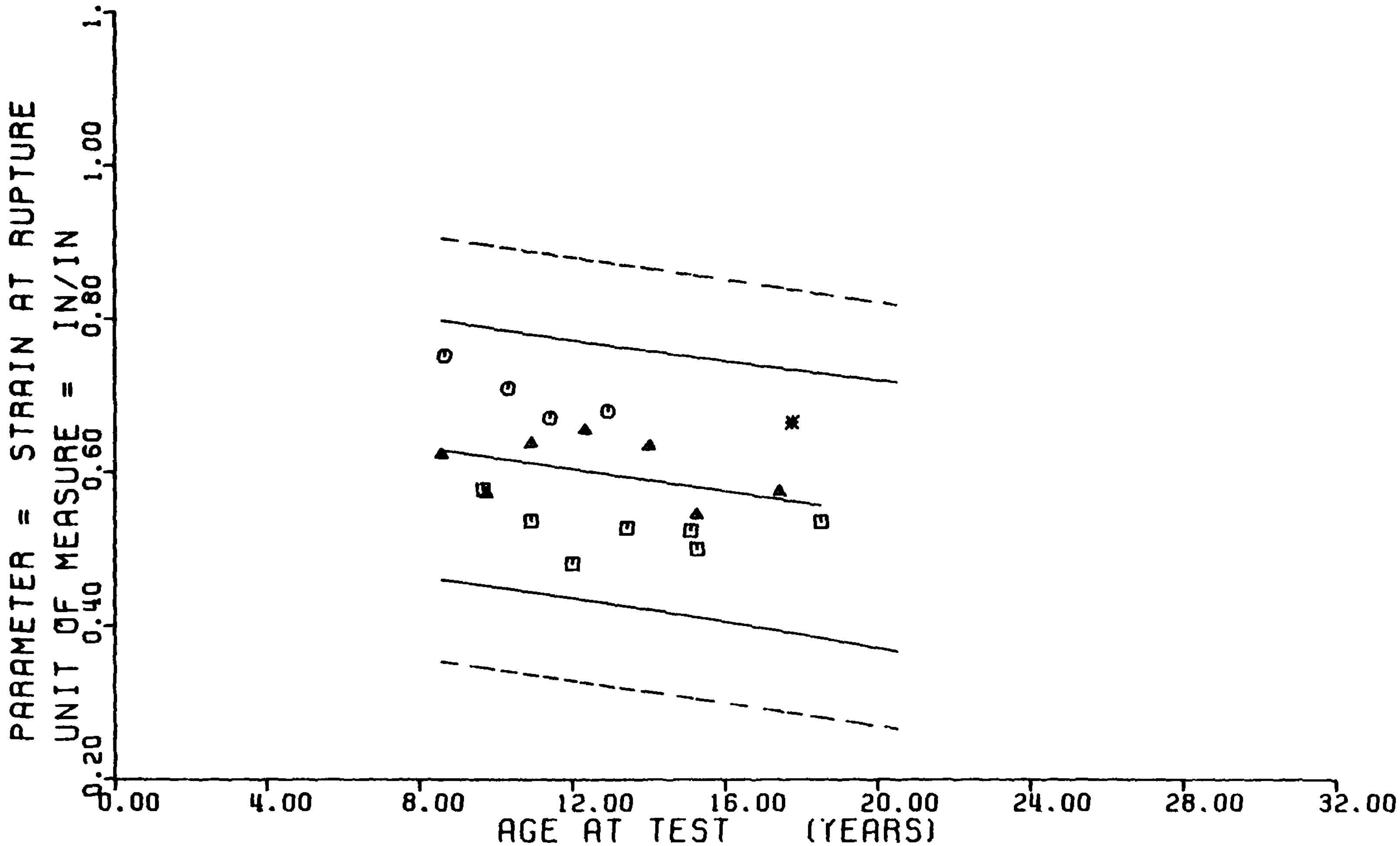
F = +5.4439671E+00 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +9.3949273E-02

R = -2.2615032E-01 SIGNIFICANCE OF R = SIGNIFICANT S_β = +2.6187726E-04

ι = +2.3332310E+00 SIGNIFICANCE OF ι = SIGNIFICANT S_ϵ = +9.1967204E-02

N = 103 DEGREES OF FREEDOM = 101

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTRS, INNER, AXIAL, H.R. HYDRO. CHS=1750 AT 500 PSI, STRAIN/RUPTURE

Figure 27

Y = ((+2.2297598E+02) + (+2.7401392E+01) * X)

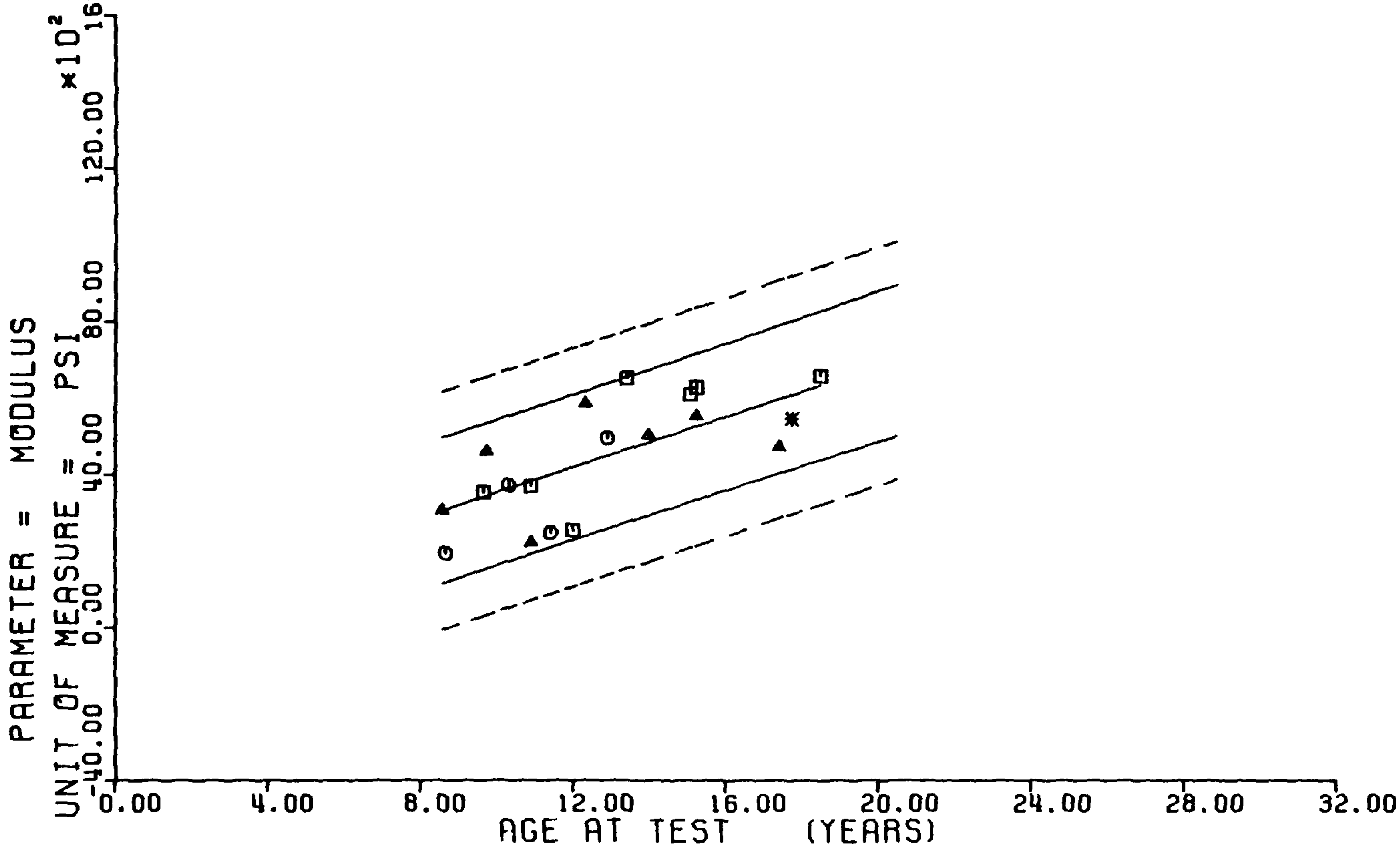
F = +8.6223512E+01   SIGNIFICANCE OF F = SIGNIFICANT σ_T = +1.4040257E+03

R = +6.7862938E-01   SIGNIFICANCE OF R = SIGNIFICANT S_B = +2.9509358E+00

ι = +9.2856616E+00   SIGNIFICANCE OF ι = SIGNIFICANT S_E = +1.0363225E+03

N = 103   DEGREES OF FREEDOM = 101

STORAGE CONDITIONS = AMB TEMP/RH   TEST CONDITIONS = AMB TEMP/RH



II STAGE OSCT MTRS, INNER, AXIAL, H.R.HYDRO.CHS=1750 AT 500 PSI, MODULUS

Figure 28

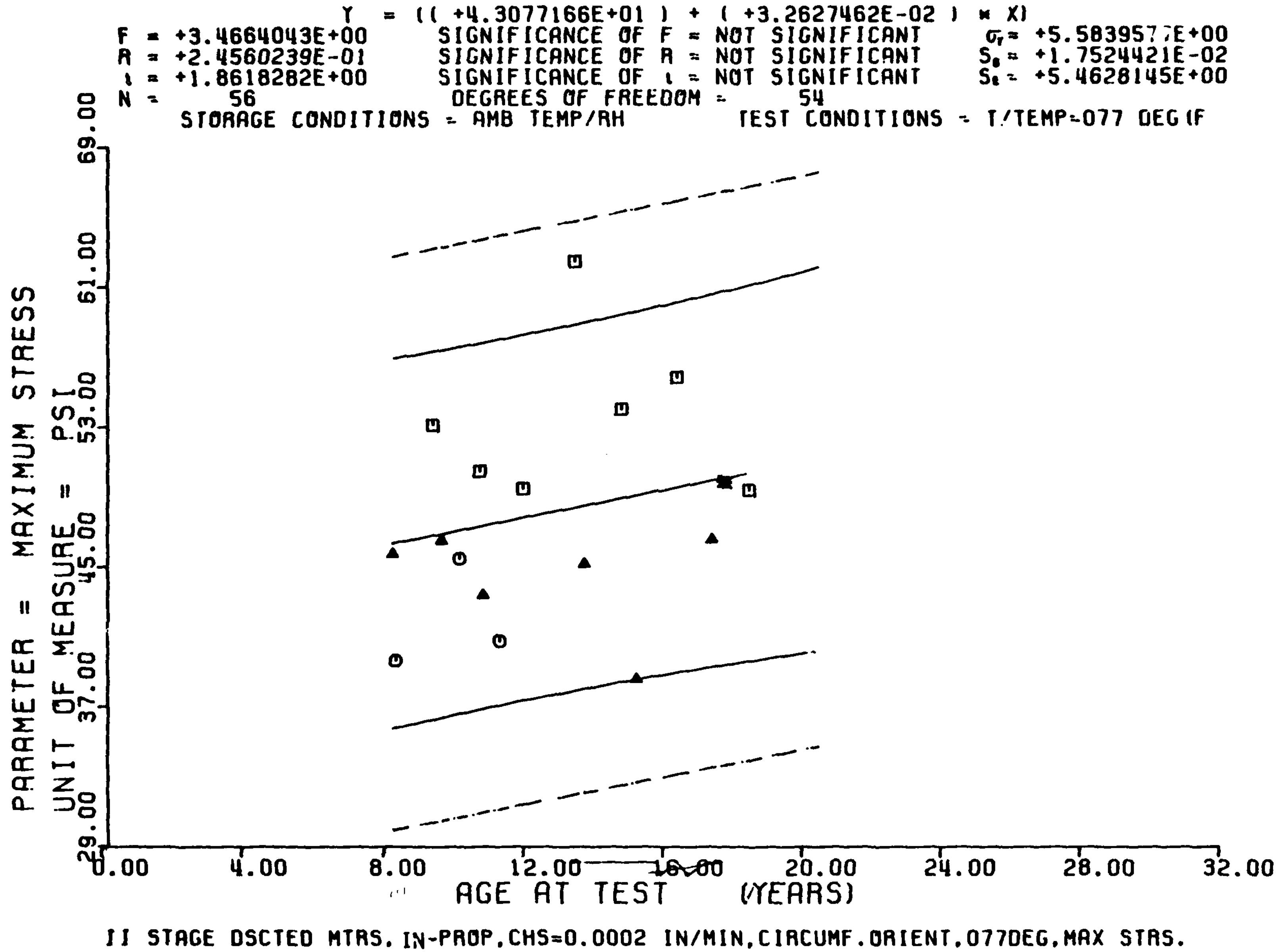

Y = ((+4.3077166E+01) + (+3.2627462E-02) * X)
F = +3.4664043E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_r = +5.583957?E+00
R = +2.4560239E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_β = +1.7524421E-02
ι = +1.8618282E+00 SIGNIFICANCE OF ι = NOT SIGNIFICANT S_ϵ = +5.4628145E+00
N = 56 DEGREES OF FREEDOM = 54
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = T/TEMP=077 DEG(F
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
69.00
61.00
53.00
45.00
37.00
29.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCTED MTRS. IN-PROP.CHS=0.0002 IN/MIN,CIRCUMF.ORIENT.077DEG.MAX STRS.

Figure 29

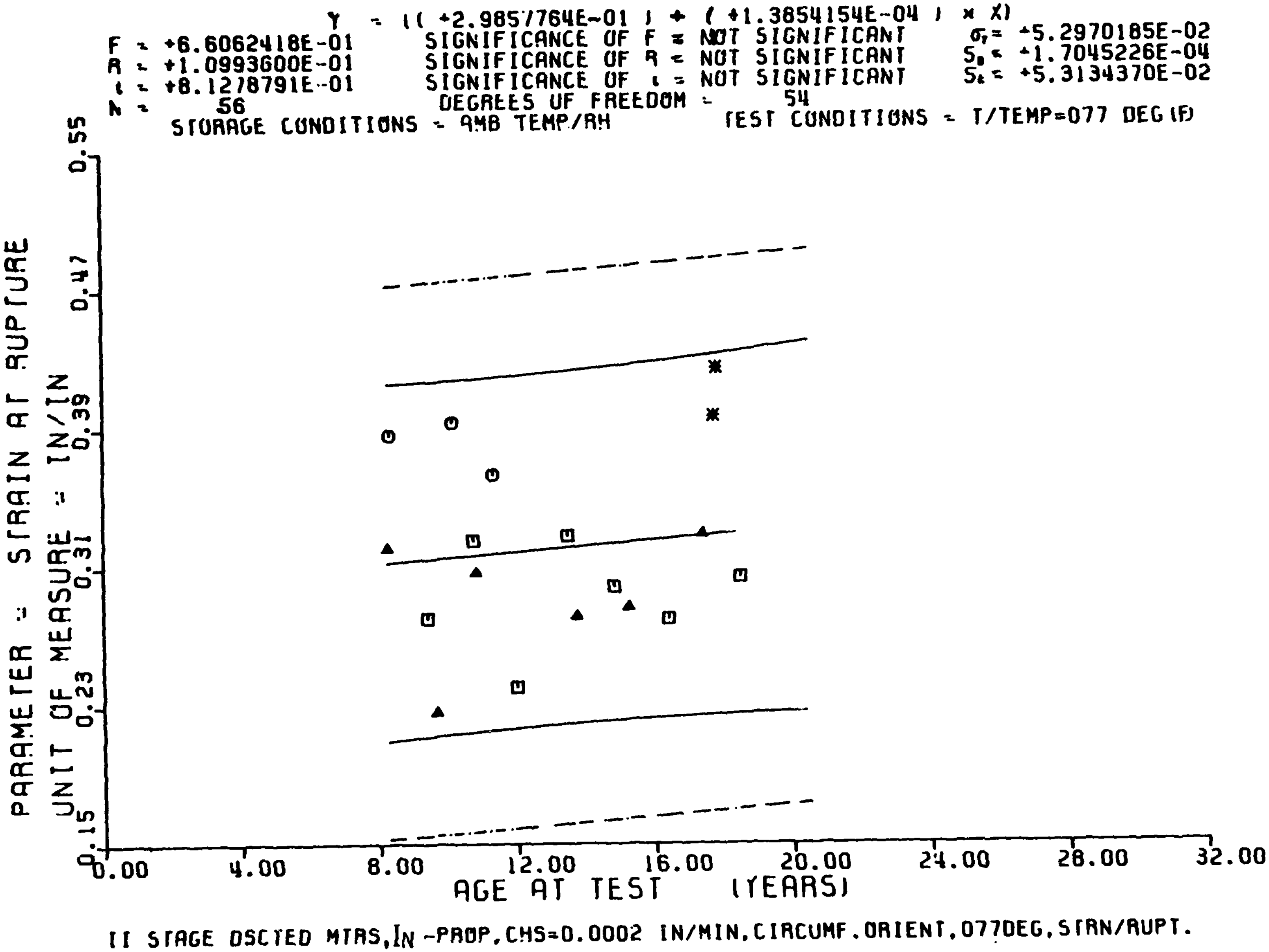
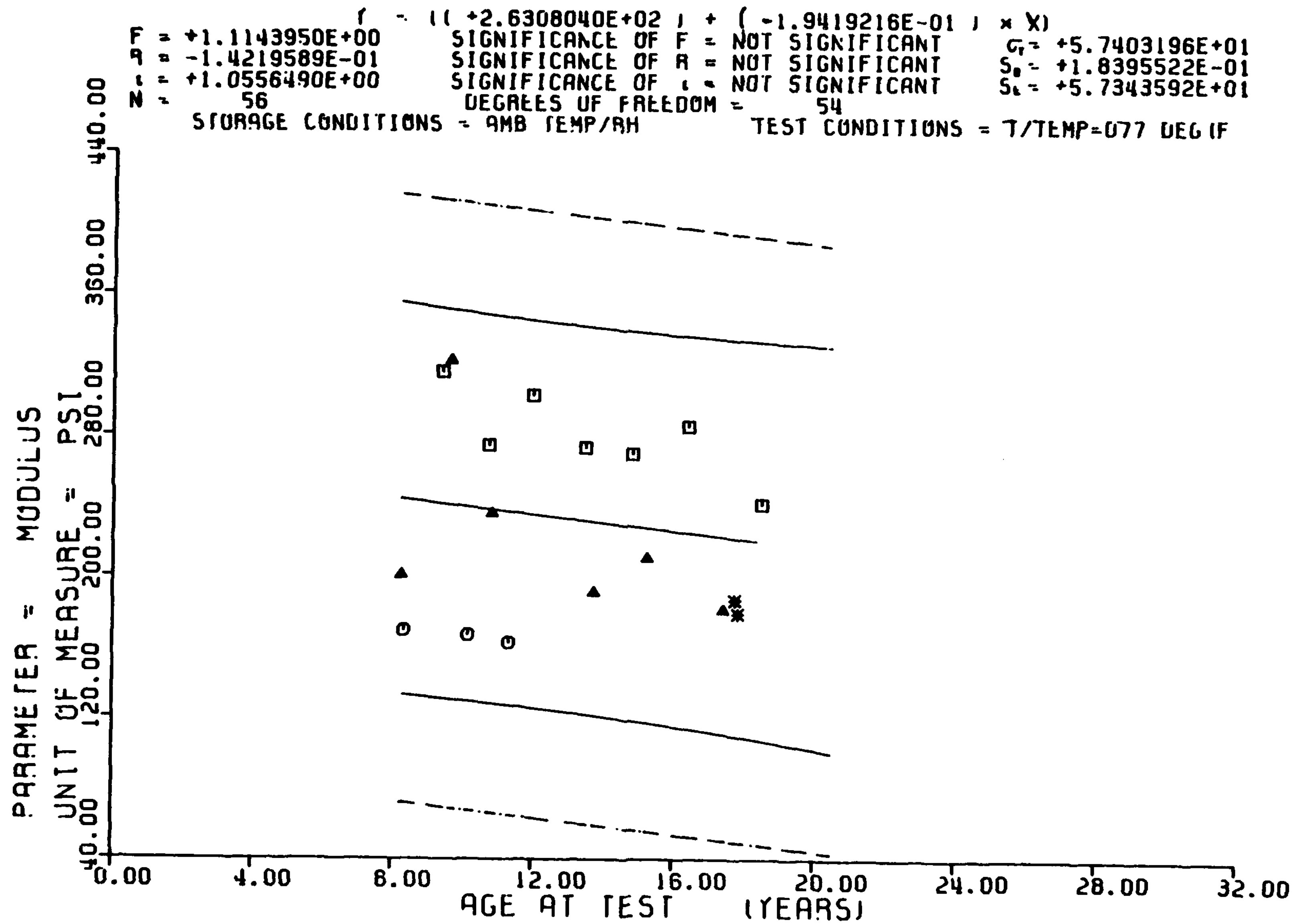

Y = ((+2.9857764E-01) + (+1.3854154E-04) × X)
F = +6.6062418E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σT= +5.2970185E-02
R = +1.0993600E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT Sb = +1.7045226E-04
t = +8.1278791E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT St = +5.3134370E-02
N = 56 DEGREES OF FREEDOM = 54
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = T/TEMP=077 DEG (F)
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = IN/IN
0.55
0.47
0.39
0.31
0.23
0.15
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCTED MTRS,IN -PROP,CHS=0.0002 IN/MIN,CIRCUMF.ORIENT,077DEG,STRN/RUPT.

Figure 30



II STAGE DSCTED MTRS,IN -PROP,CHS=0.0002 IN/MIN,CIRCUMF.ORIENT,077DEG,MODULUS.

Figure 31

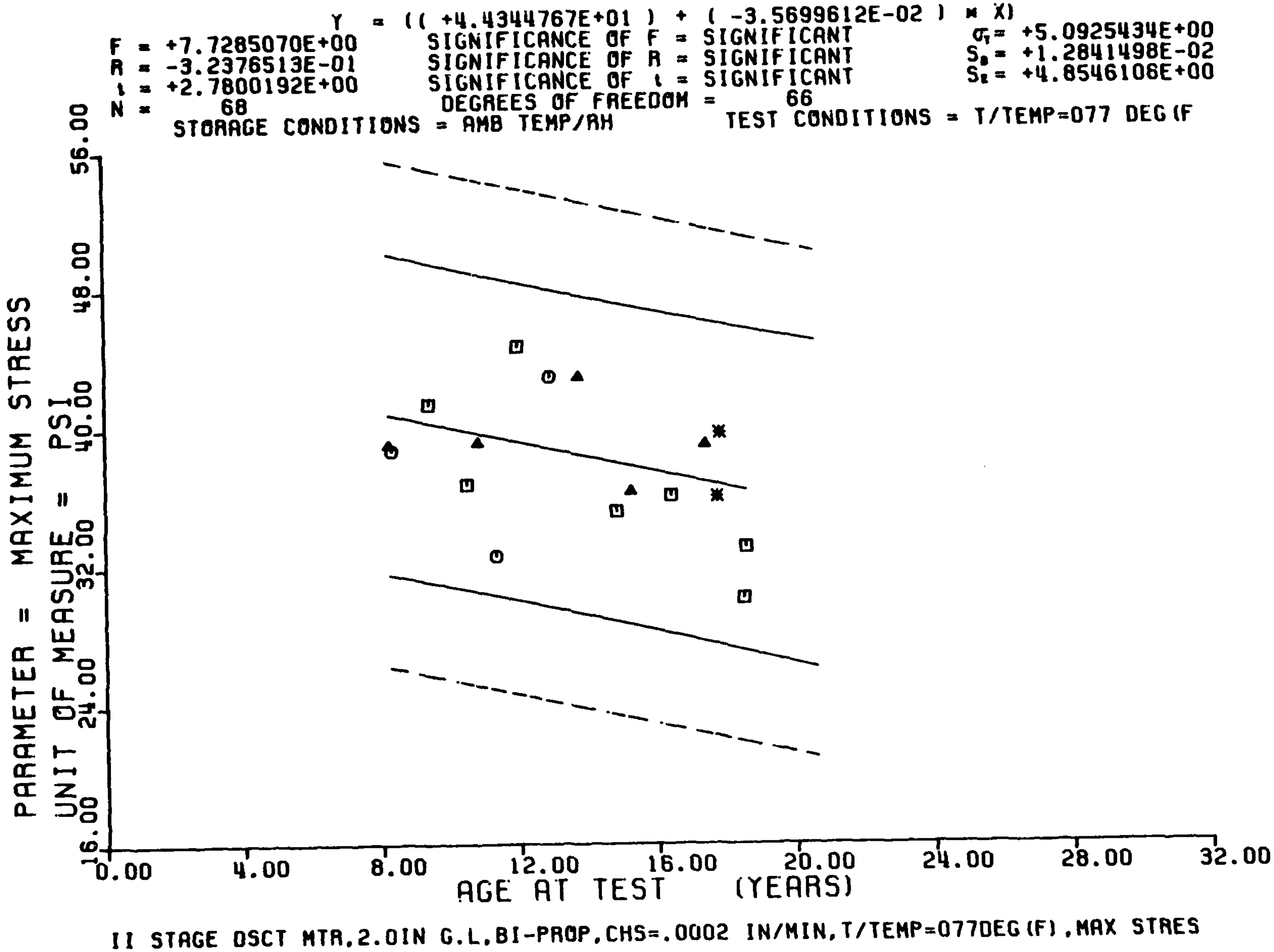

Y = ((+4.4344767E+01) + (-3.5699612E-02) * X)
F = +7.7285070E+00
R = -3.2376513E-01
t = +2.7800192E+00
N = 68
SIGNIFICANCE OF F = SIGNIFICANT
SIGNIFICANCE OF R = SIGNIFICANT
SIGNIFICANCE OF t = SIGNIFICANT
DEGREES OF FREEDOM = 66
σT = +5.0925434E+00
SB = +1.2841498E-02
SE = +4.8546106E+00
STORAGE CONDITIONS = AMB TEMP/RH
TEST CONDITIONS = T/TEMP=077 DEG(F
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
56.00
48.00
40.00
32.00
24.00
16.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
II STAGE DSCT MTR,2.0IN G.L,BI-PROP,CHS=.0002 IN/MIN,T/TEMP=077DEG(F),MAX STRES

Figure 32

Y = ((+2.3866922E-01) + (-4.1425974E-05) * X)

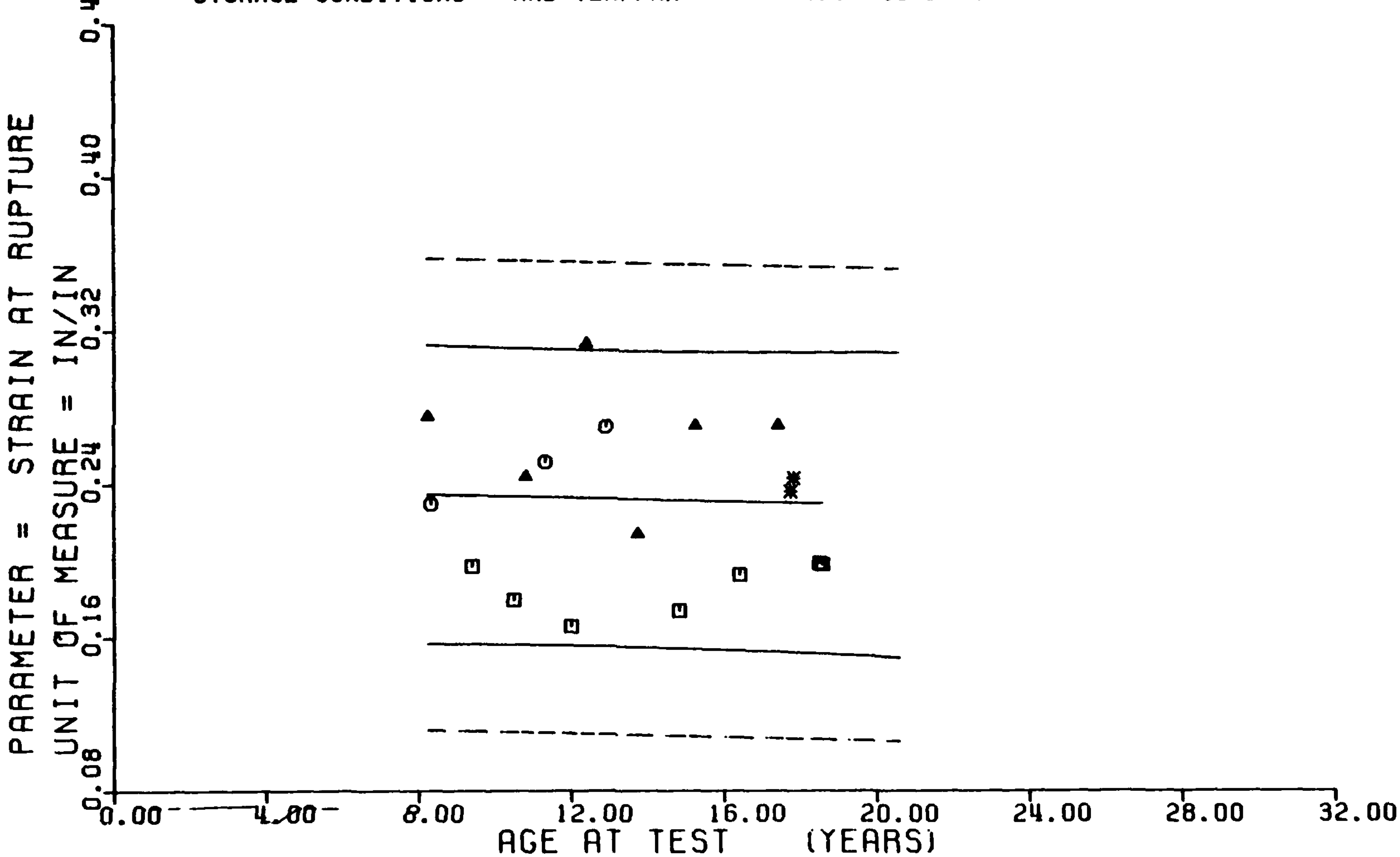
F = +1.4598597E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +4.0725857E-02

R = -4.6979005E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +1.0842193E-04

t = +3.8208110E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +4.0987921E-02

N = 68 DEGREES OF FREEDOM = 66

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = T/TEMP=077 DEG(F



II STAGE DSCT MTR,2.0IN G.L,BI-PROP,CHS=.0002 IN/MIN,T/TEMP=077 DEG(F),STRN/RUP

Figure 33

Y = ((+3.0263716E+02) + (-2.2974555E-01) * X)

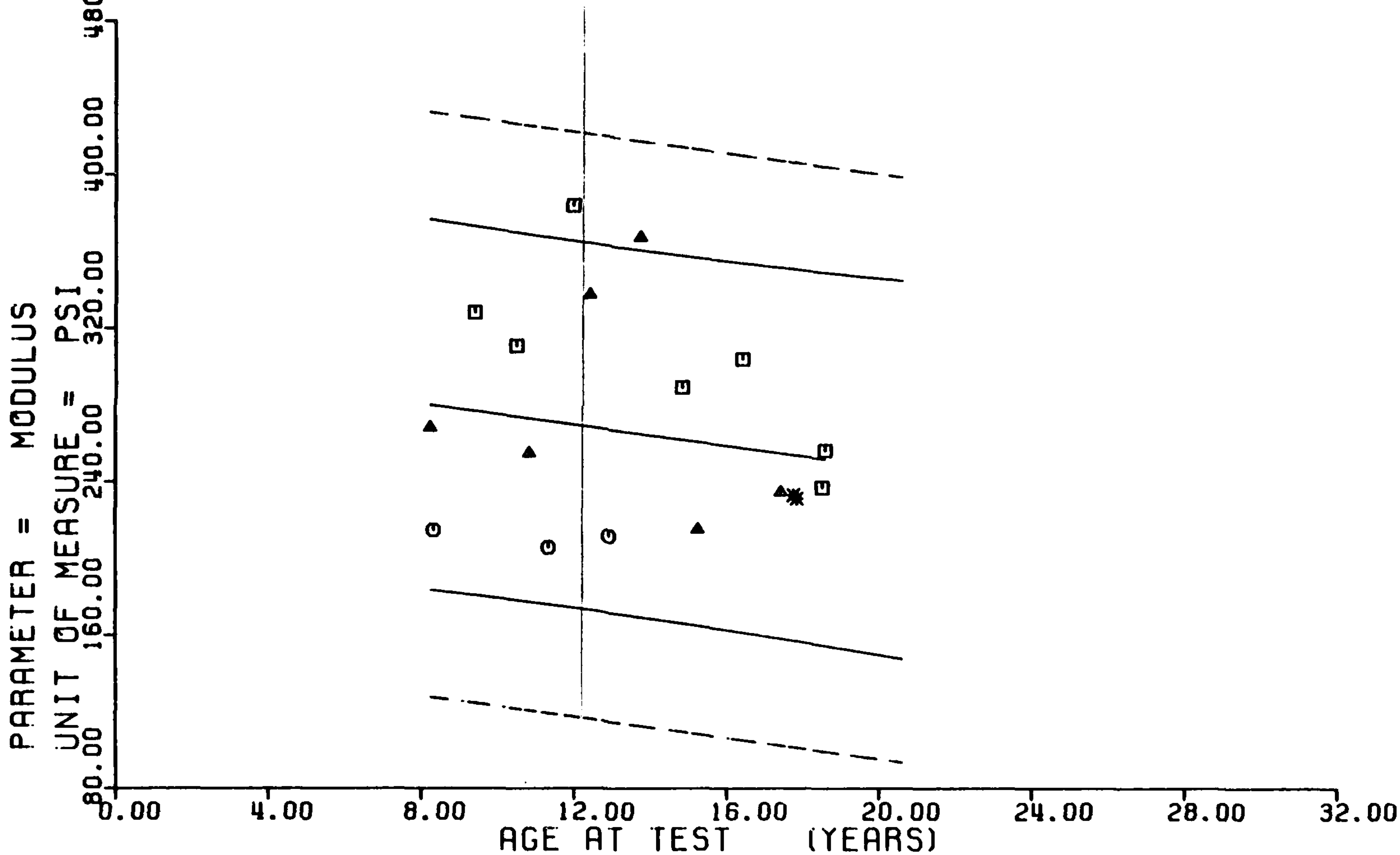
F = +2.9261147E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_T = +5.1498510E+01

R = -2.0604105E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +1.3430786E-01

t = +1.7105889E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +5.0773858E+01

N = 68 DEGREES OF FREEDOM = 66

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = T/TEMP=077 DEG(F



II STAGE DSCT MTR,2.0IN G.L,BI-PROP,CHS=.0002 IN/MIN,T/TEMP=077 DEG(F),MODULUS

Figure 34

Y = ((+8.2131957E+02) + (-1.2128622E+00) * X)

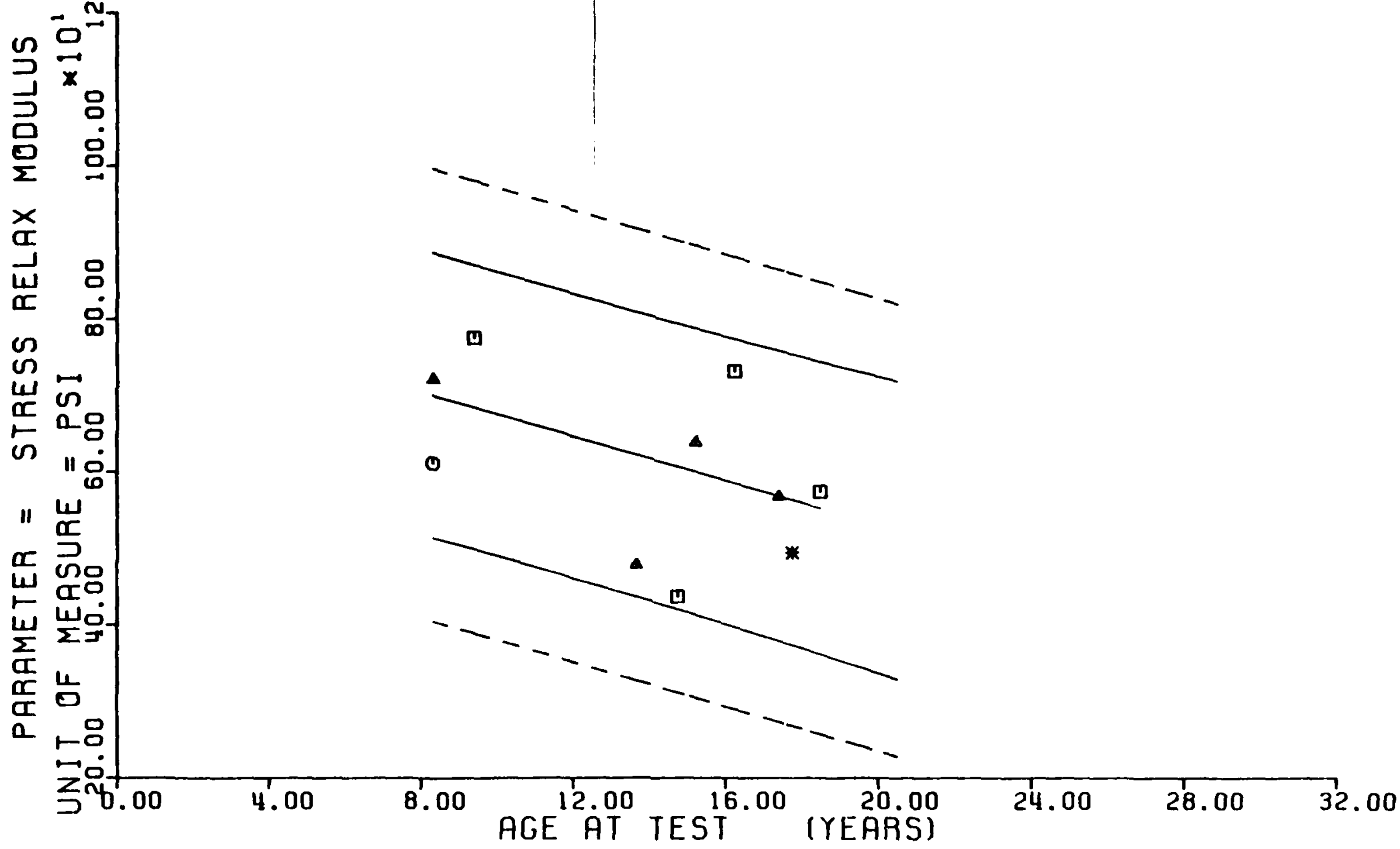
F = +1.9261267E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +1.1114248E+02

R = -4.7529860E-01 SIGNIFICANCE OF R = SIGNIFICANT S_β = +2.7635609E-01

ι = +4.3887660E+00 SIGNIFICANCE OF ι = SIGNIFICANT S_ε = +9.8523904E+01

N = 68 DEGREES OF FREEDOM = 66

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = TEMP +77 DEG F.



STAGE II,DISSECTED MTRS,OUTER,STRESS RELAXATION,3 PERCENT,+77 DEG.10/SEC.

Figure 35

Y = ((+6.2102192E+02) + (-9.9377701E-01) * X)

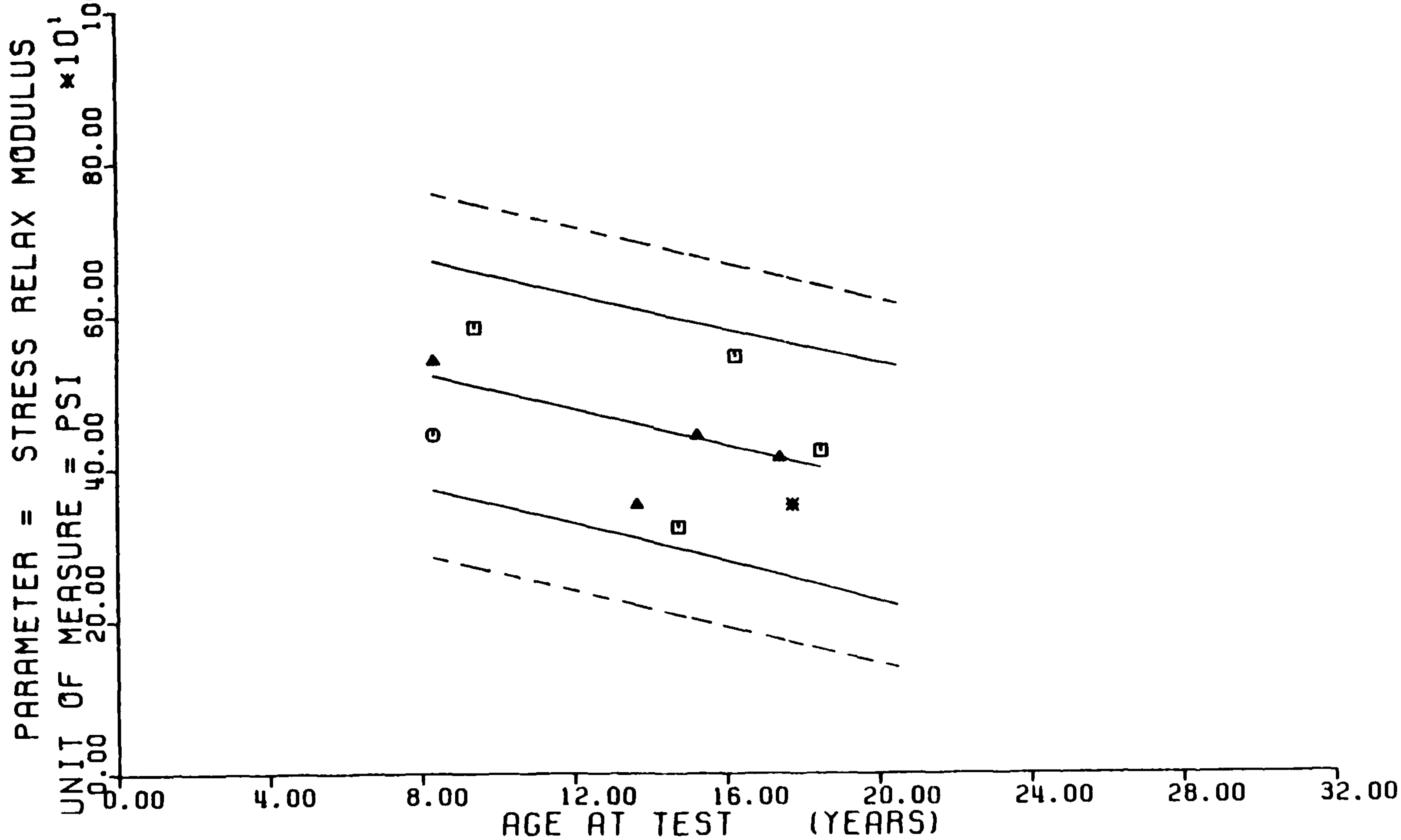
F = +1.9958435E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +8.9826634E+01

R = -4.8185790E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +2.2244656E-01

t = +4.4674864E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +7.9304581E+01

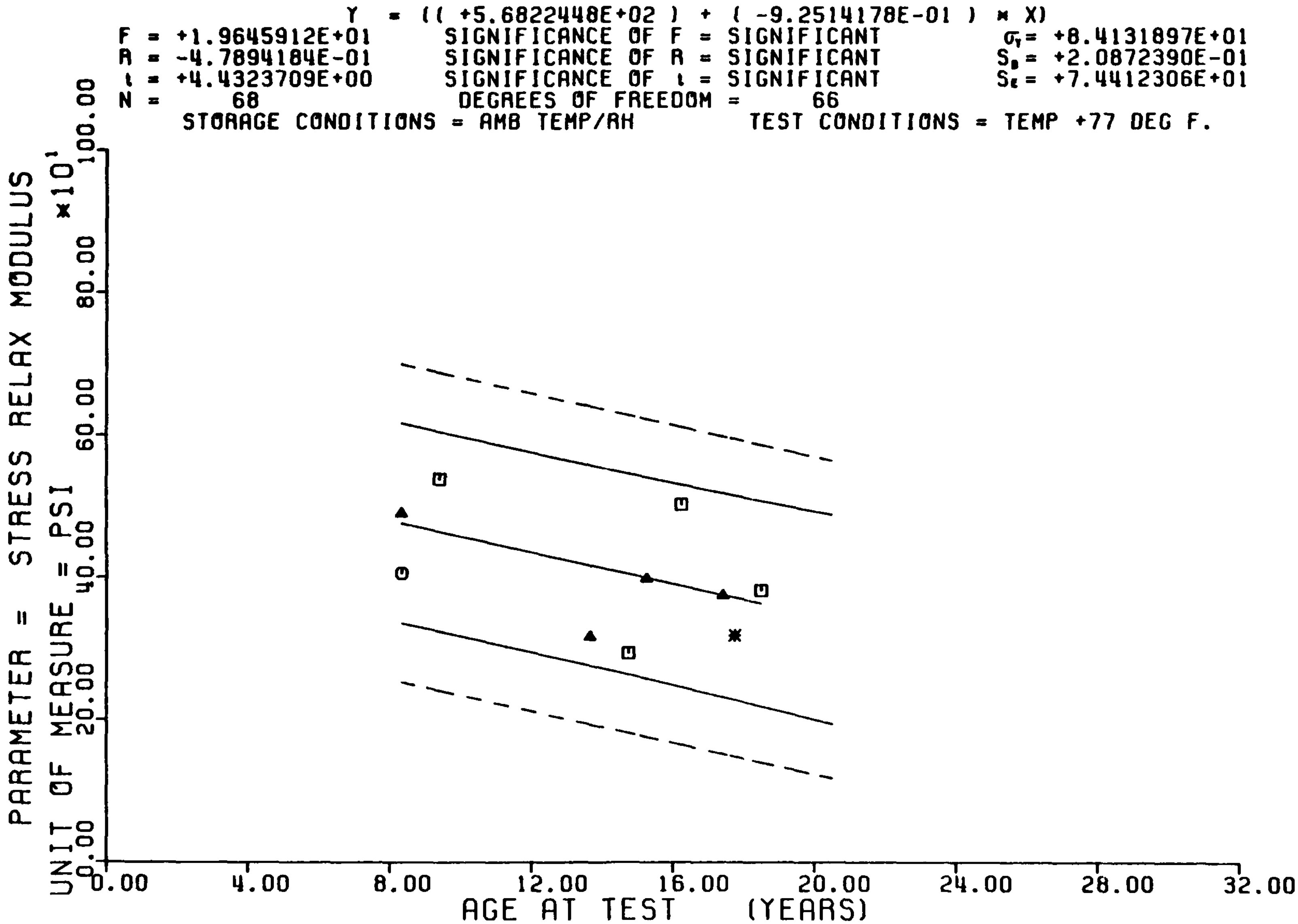
N = 68 DEGREES OF FREEDOM = 66

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = TEMP +77 DEG F.



STAGE II,DISSECTED MTRS,OUTER,STRESS RELAXATION,3 PERCENT,+77 DEG,50/SEC.

Figure 36



STAGE II,DISSECTED MTRS,OUTER,STRESS RELAXATION,3 PERCENT,+77 DEG,100/SEC.

Figure 37

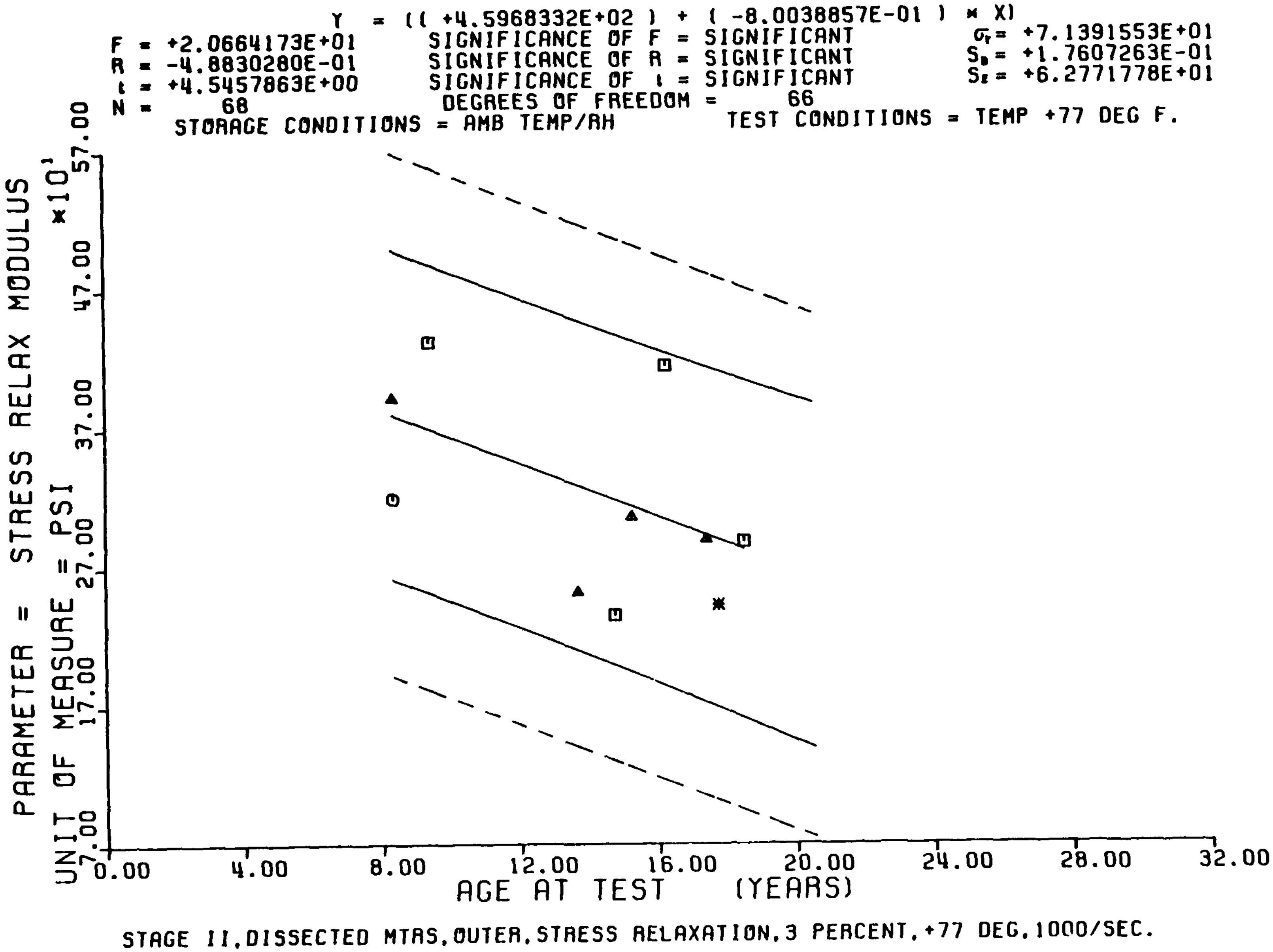

Y = ((+4.5968332E+02) + (-8.0038857E-01) * X)
F = +2.0664173E+01
SIGNIFICANCE OF F = SIGNIFICANT
σ = +7.1391553E+01
R = -4.8830280E-01
SIGNIFICANCE OF R = SIGNIFICANT
S_b = +1.7607263E-01
t = +4.5457863E+00
SIGNIFICANCE OF t = SIGNIFICANT
S_E = +6.2771778E+01
N = 68
DEGREES OF FREEDOM = 66
STORAGE CONDITIONS = AMB TEMP/RH
TEST CONDITIONS = TEMP +77 DEG F.
PARAMETER = STRESS RELAX MODULUS
UNIT OF MEASURE = PSI
×10¹
57.00
47.00
37.00
27.00
17.00
7.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
STAGE II,DISSECTED MTRS,OUTER,STRESS RELAXATION,3 PERCENT,+77 DEG,1000/SEC.

Figure 38

Y = ((+5.2388844E+02) + (+2.4388250E-01) * X)

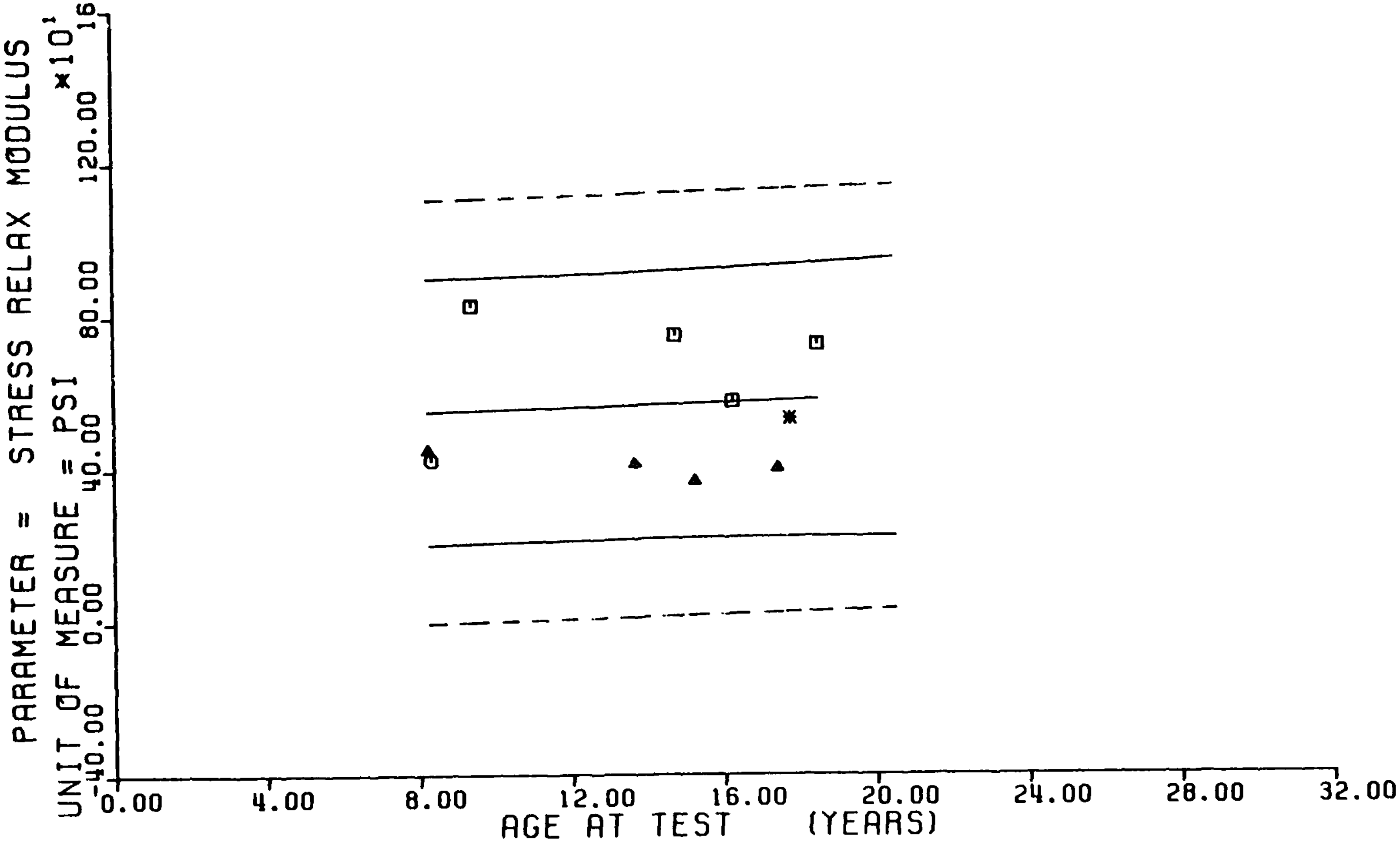
F = +2.2846766E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +1.8306134E+02

R = +5.8295598E-0^ SIGNIFICANCE OF R = NOT SIGNIFICANT S_b = +5.1023268E-01

t = +4.7798291E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +1.8410877E+02

N = 69 DEGREES OF FREEDOM = 67

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = TEMP +77 DEG F.



STAGE II, DISSECTED MTRS, INNER, STRESS RELAXATION, 3 PERCENT, +77 DEG, 10/SEC.

Figure 39

Y = ((+3.7361055E+02) + (+2.2529144E-01) * X)

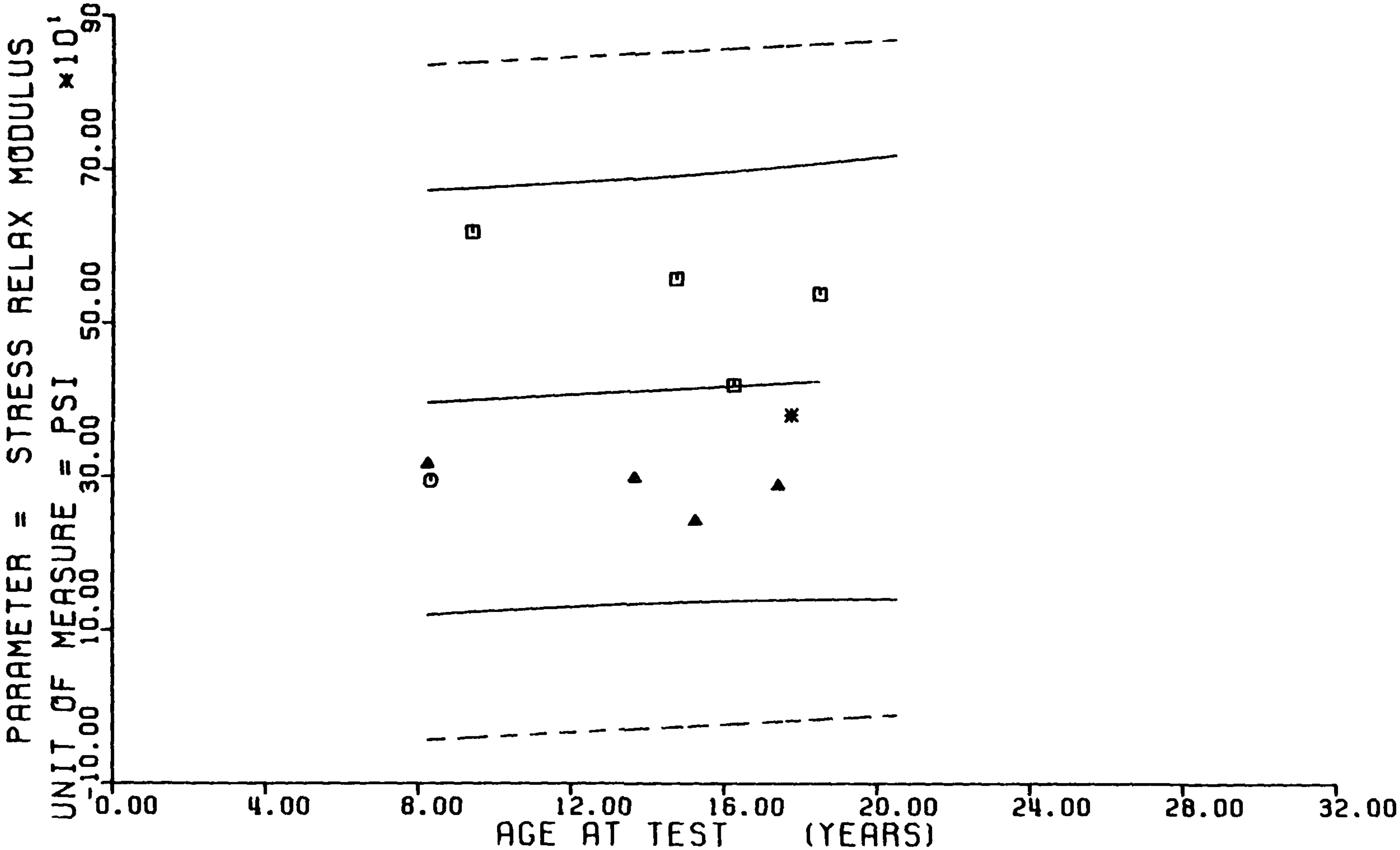
F = +3.0790766E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +1.4575358E+02

R = +6.7635889E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +4.0600785E-01

t = +5.5489428E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +1.4650102E+02

N = 69 DEGREES OF FREEDOM = 67

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = TEMP +77 DEG F.



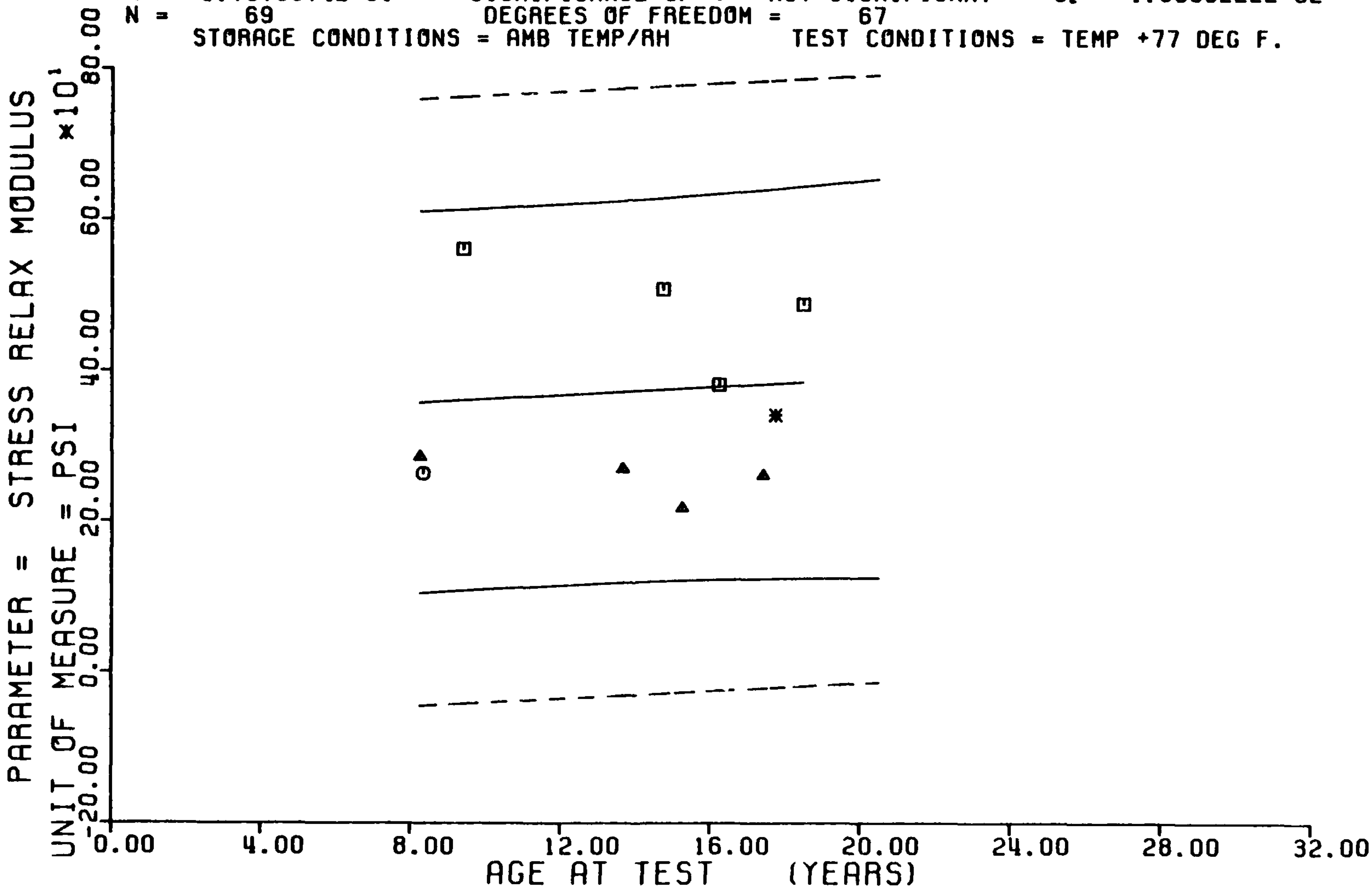
STAGE II,DISSECTED MTRS,INNER,STRESS RELAXATION,3 PERCENT,+77 DEG,50/SEC.

Figure 40

$Y = ((+3.3545536E{+}02) + (+2.1523837E{-}01) \times X)$

F = +3.3611440E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +1.3330668E+02
R = +7.0651199E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +3.7125827E-01
t = +5.7975374E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +1.3396222E+02
N = 69 DEGREES OF FREEDOM = 67

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = TEMP +77 DEG F.



STAGE II,DISSECTED MTRS,INNER,STRESS RELAXATION,3 PERCENT,+77 DEG,100/SEC.

Figure 41

Y = ((+2.6193300E+02) + (+1.5919201E-01) * X)

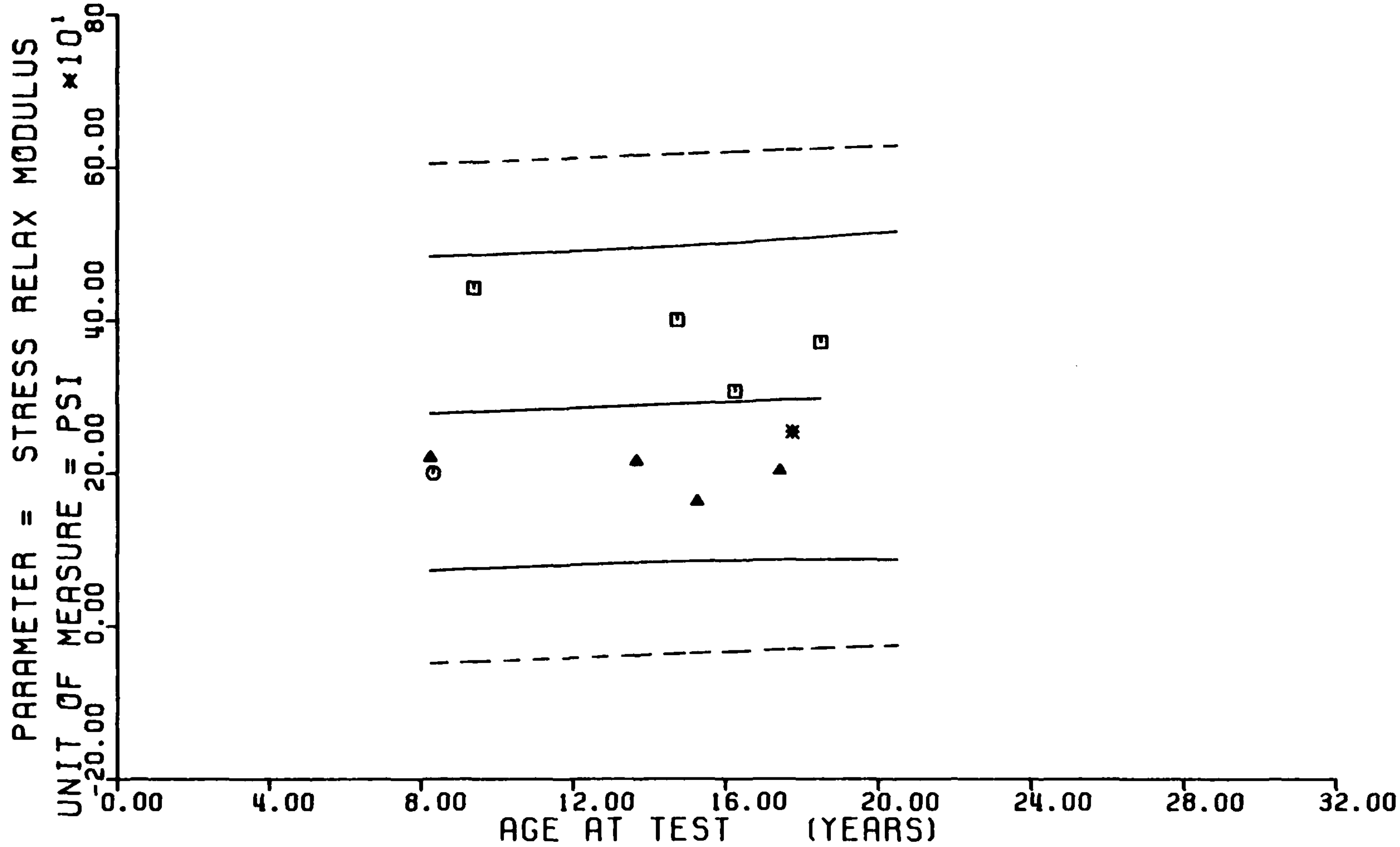
F = +2.7866731E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +1.0823524E+02

R = +6.4358265E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +3.0156314E-01

t = +5.2788949E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +1.0881392E+02

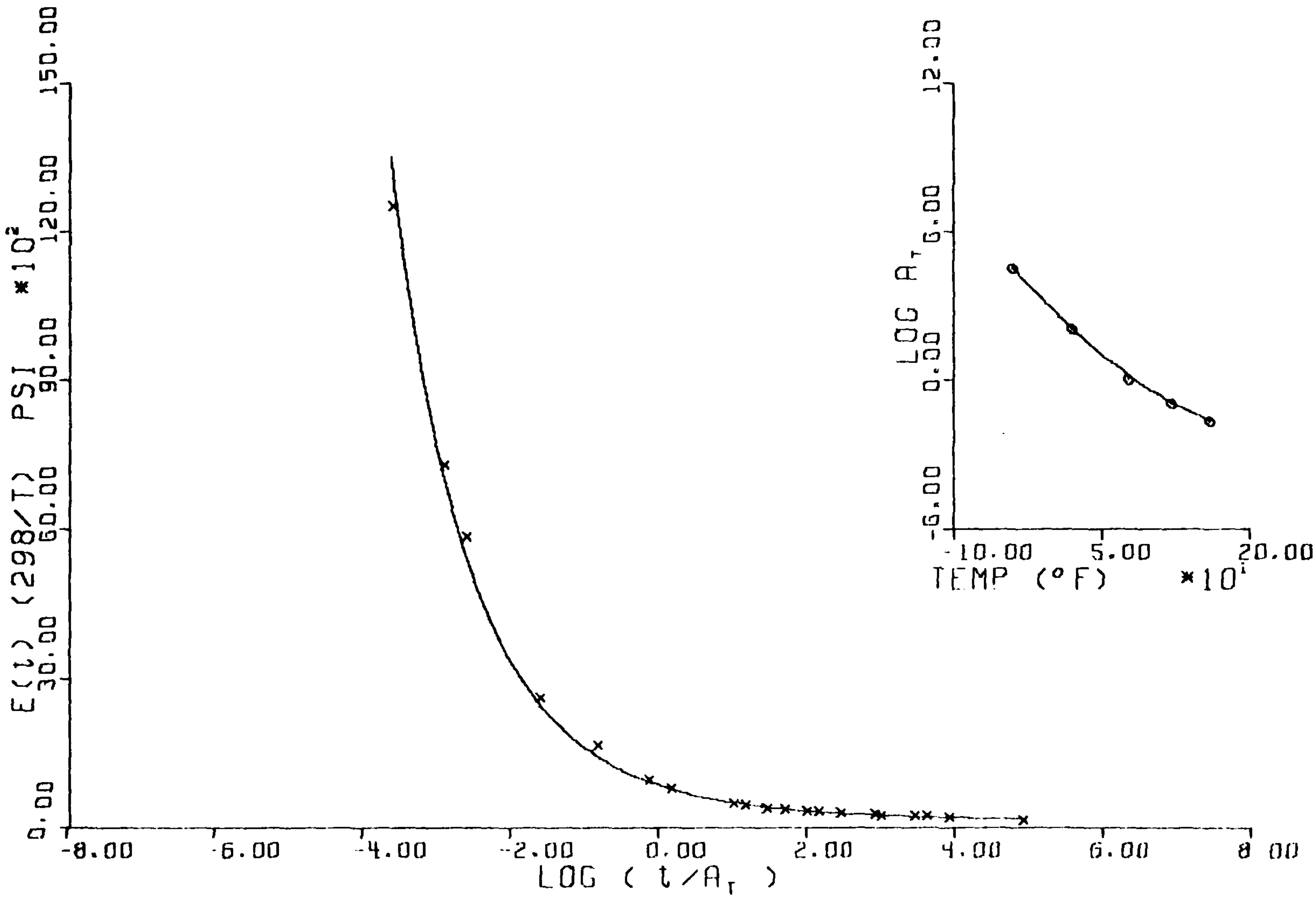
N = 69 DEGREES OF FREEDOM = 67

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = TEMP +77 DEG F.



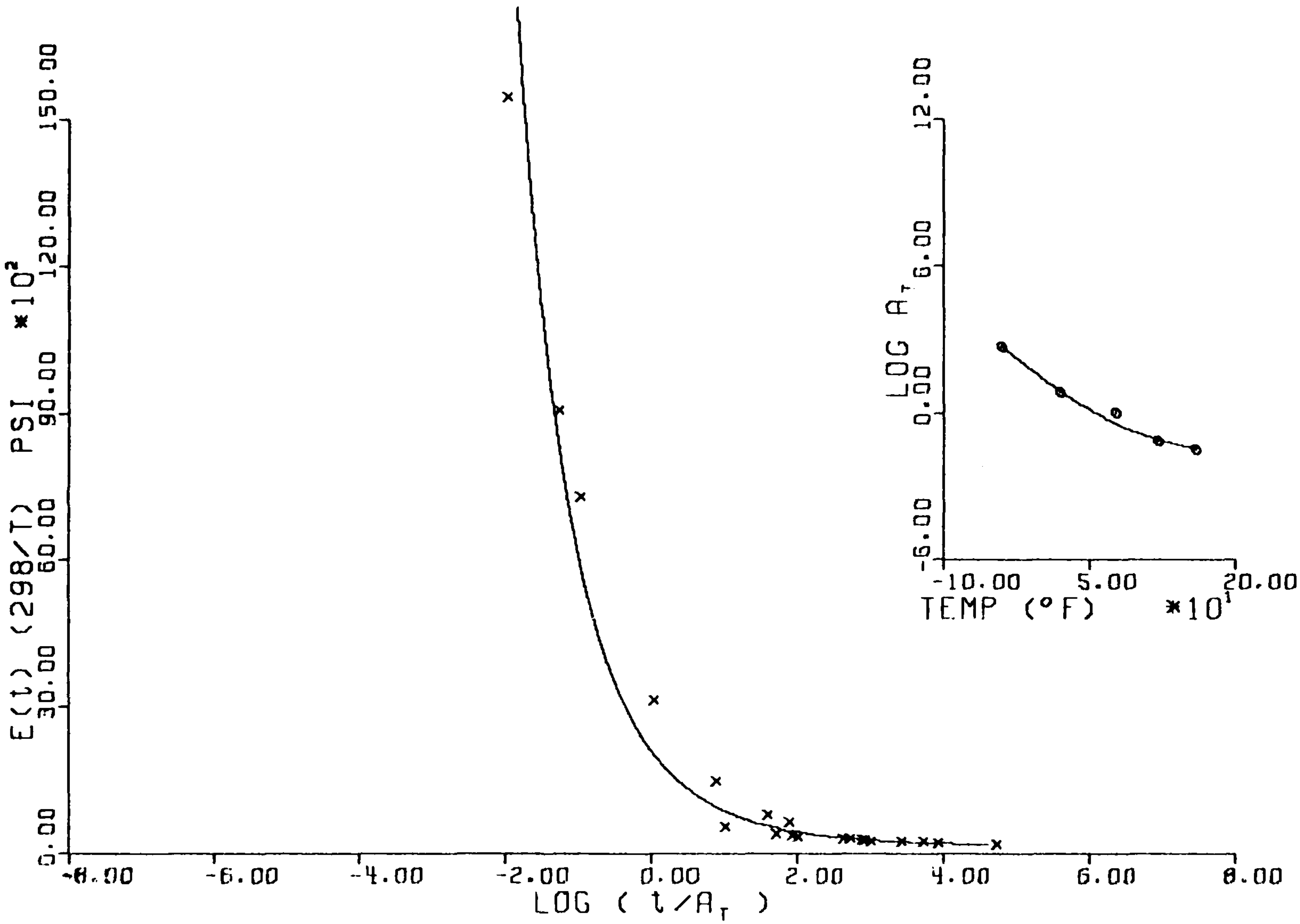
STAGE II,DISSECTED MTRS,INNER,STRESS RELAXATION,3 PERCENT,+77 DEG,1000/SEC.

Figure 42



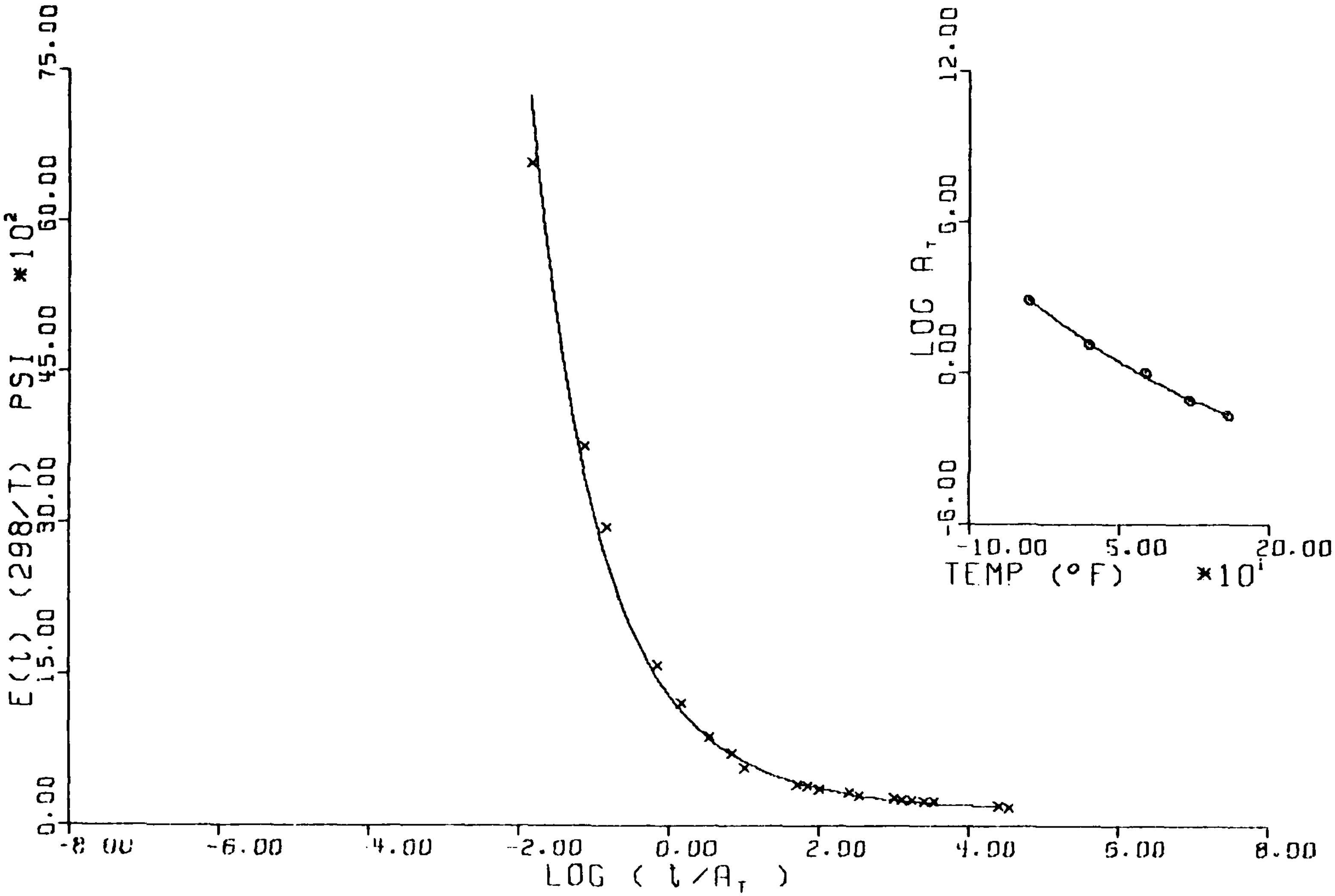
STAGE II DISCTED MOTOR(0022687). OUTER,3% STRAIN. MASTER STRESS RELAXATION,198:2

Figure 43



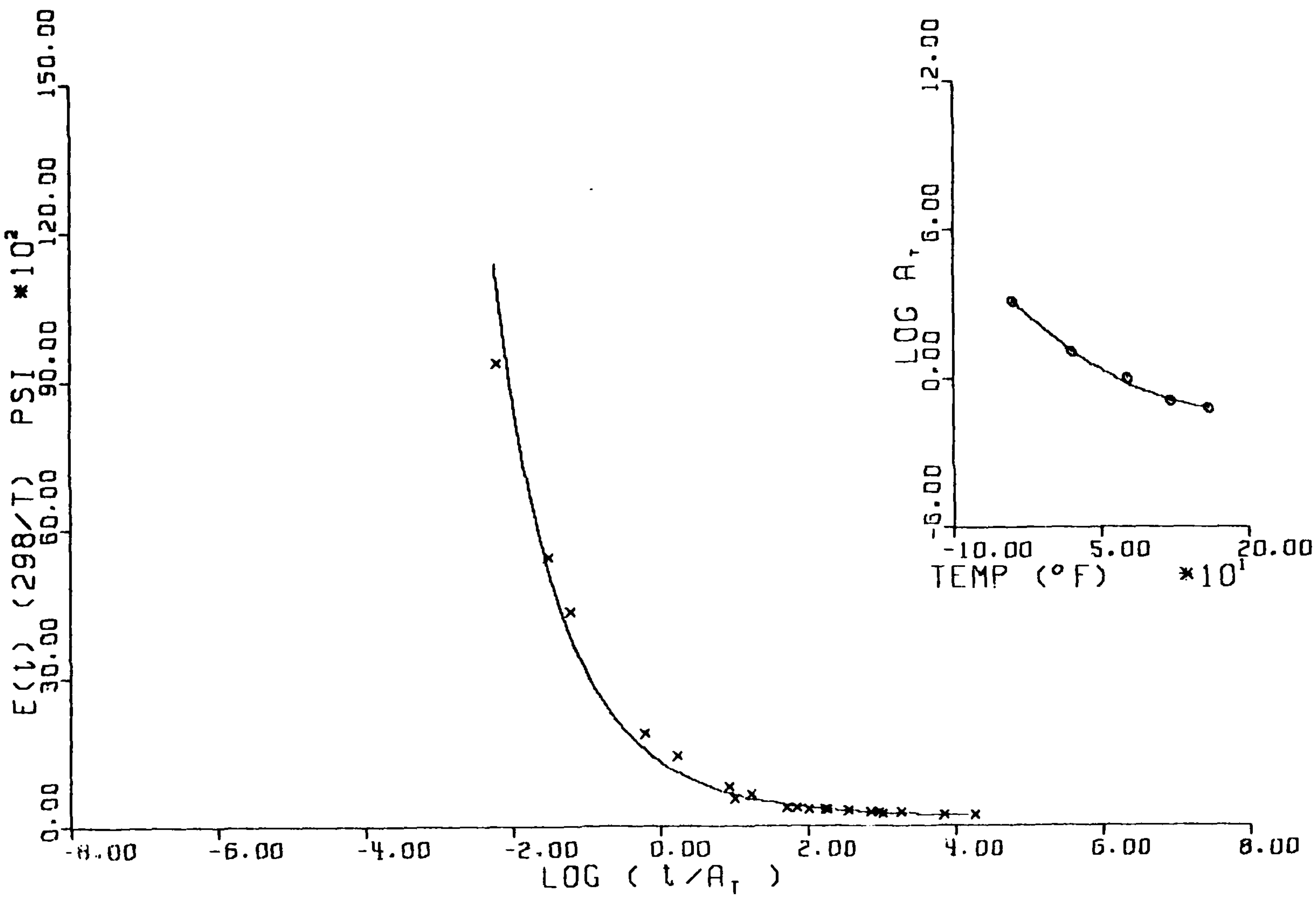
STAGE II DISCTED MOTOR(0022687), INNER,3% STRAIN, MASTER STRESS RELAXATION,1982.

Figure 44



STAGE II DISCTED MOTOR(0022687), OUTER,5% STRAIN, MASTER STRESS RELAXATION,1982.

Figure 45



STAGE II DISCTED MOTOR(0022687). INNER, 5% STRAIN. MASTER STRESS RELAXATION. 3982.

Figure 46

Y = ((+2.2832202E-01) + (+3.6830316E-04) * X)

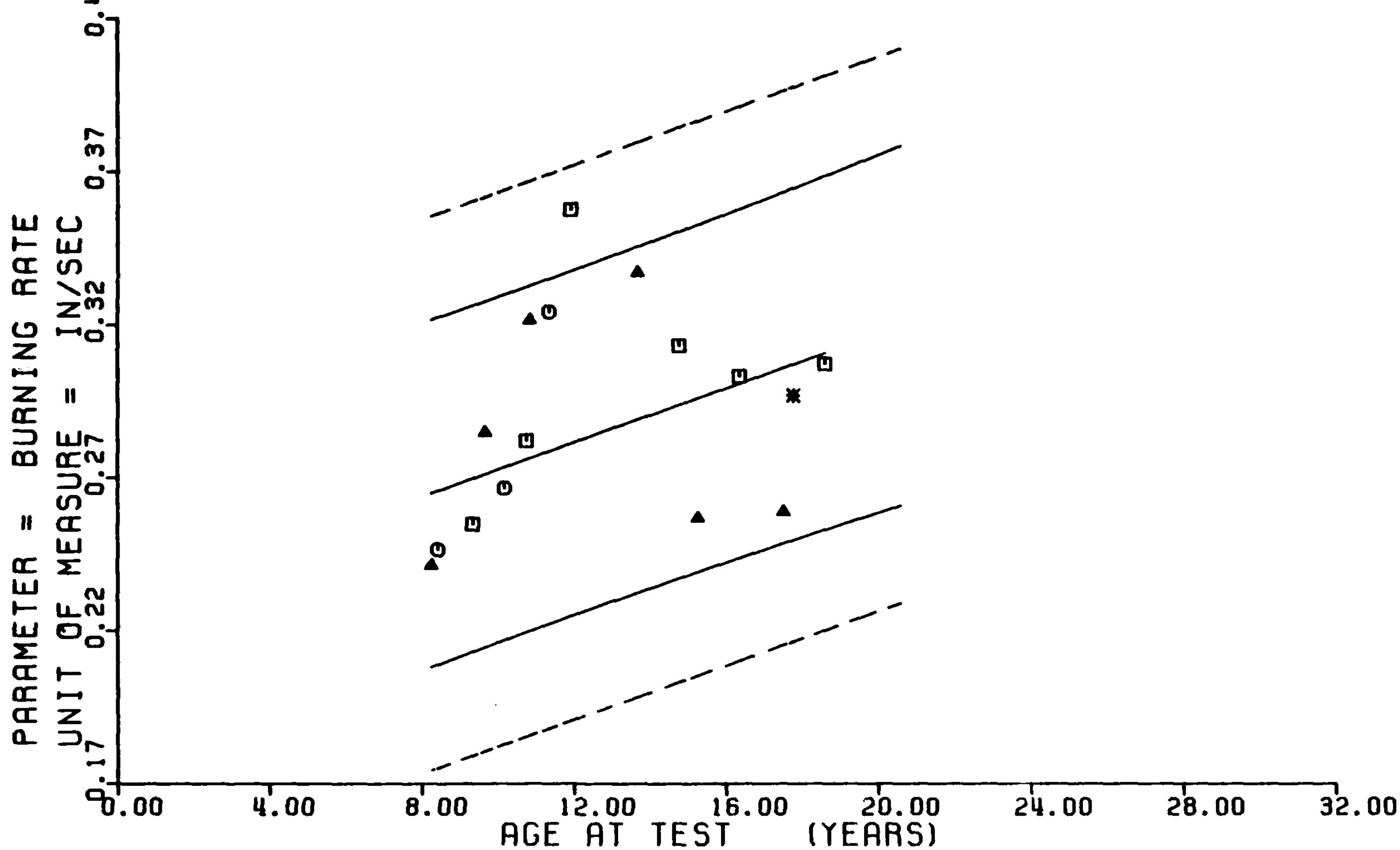
F = +1.8842533E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +3.3575312E-02

R = +4.5294734E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +8.4846866E-05

t = +4.3407986E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +3.0137970E-02

N = 75 DEGREES OF FREEDOM = 73

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 500 PSI



STAGE II DISSECTED MTRS, OUTER, BURNING RATE AT 500 PSI

Figure 47

Y = ((+3.4207834E-01) + (+1.8044108E-04) * X)

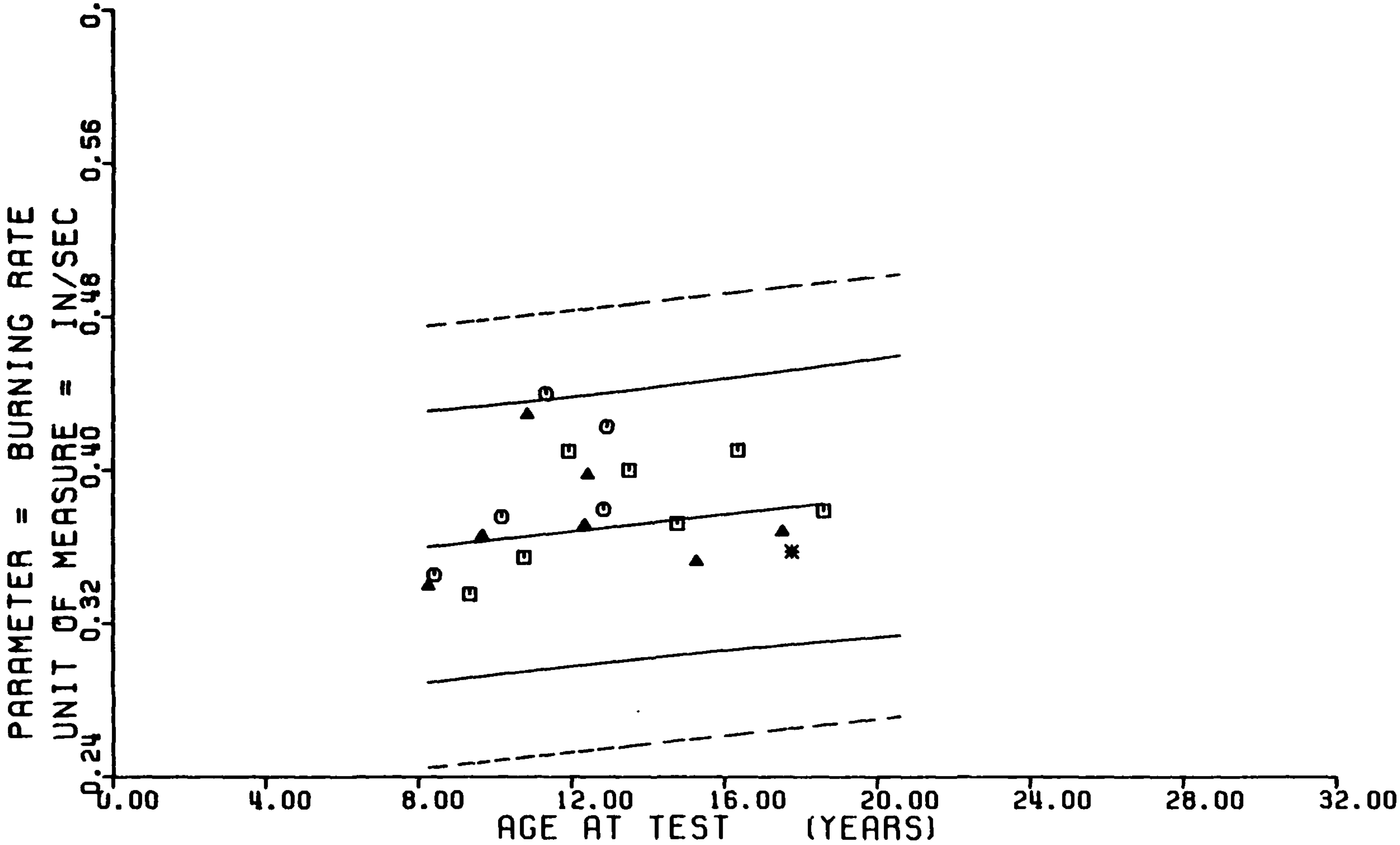
F = +2.8738096E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +3.8763434E-02

R = +1.6713853E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +1.0644038E-04

t = +1.6952314E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +3.8408781E-02

N = 102 DEGREES OF FREEDOM = 100

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 500 PSI



STAGE II DISSECTED MTRS, INNER, BURNING RATE AT 500 PSI

Figure 48

Y = ((+5.5571345E-05) + (+3.3664008E-08) × X)

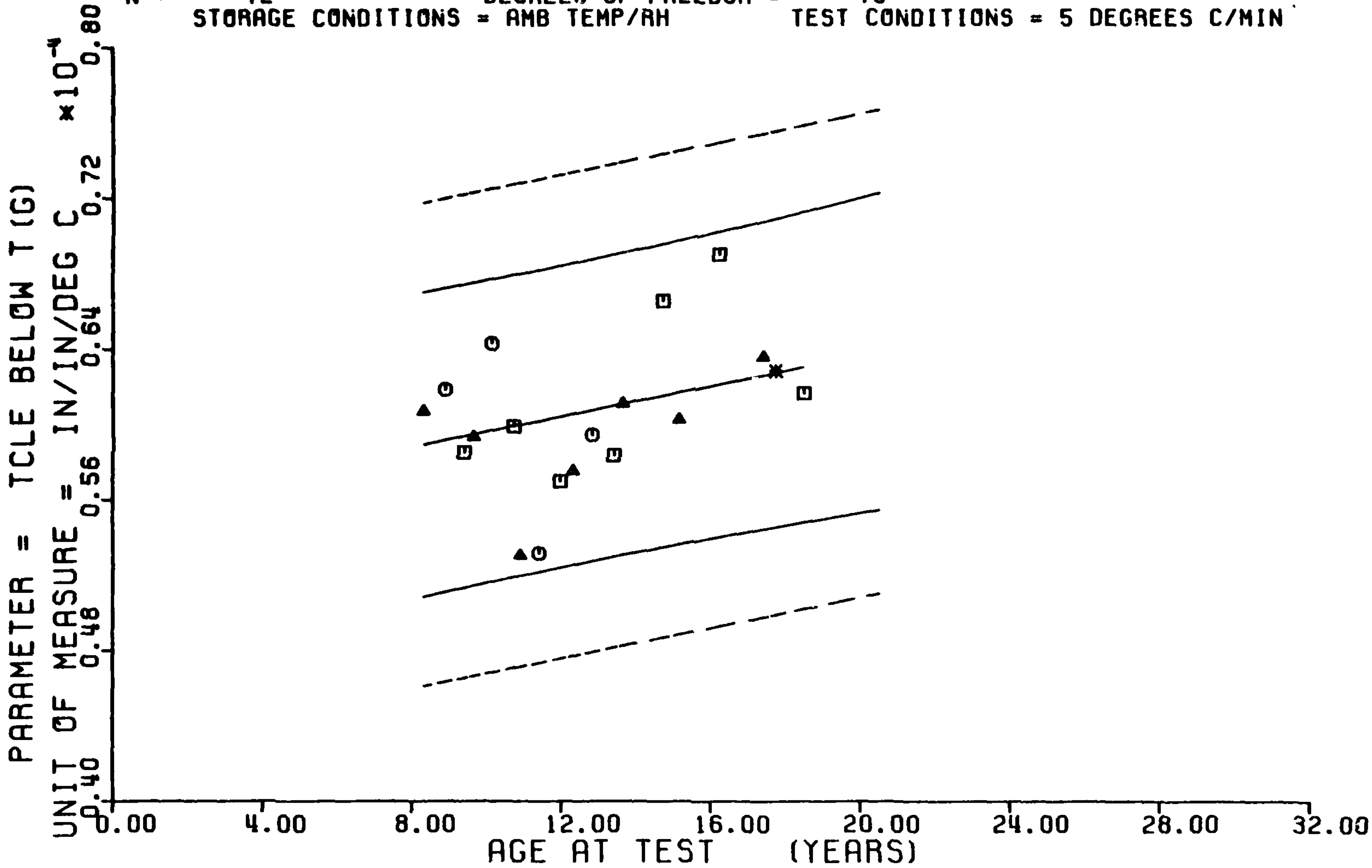
F = +6.3386407E+00 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +4.4342755E-06

R = +2.8815479E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +1.3371119E-08

t = +2.5176657E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +4.2764129E-06

N = 72 DEGREES OF FREEDOM = 70

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 5 DEGREES C/MIN



STAGE II DISSECTED MTRS,OUTER,THERMAL COEFFICIENT OF LINEAR EXPANSION BELOW TG

Figure 49

Y = ((+7.0174720E-05) + (+1.4719630E-07) * X)

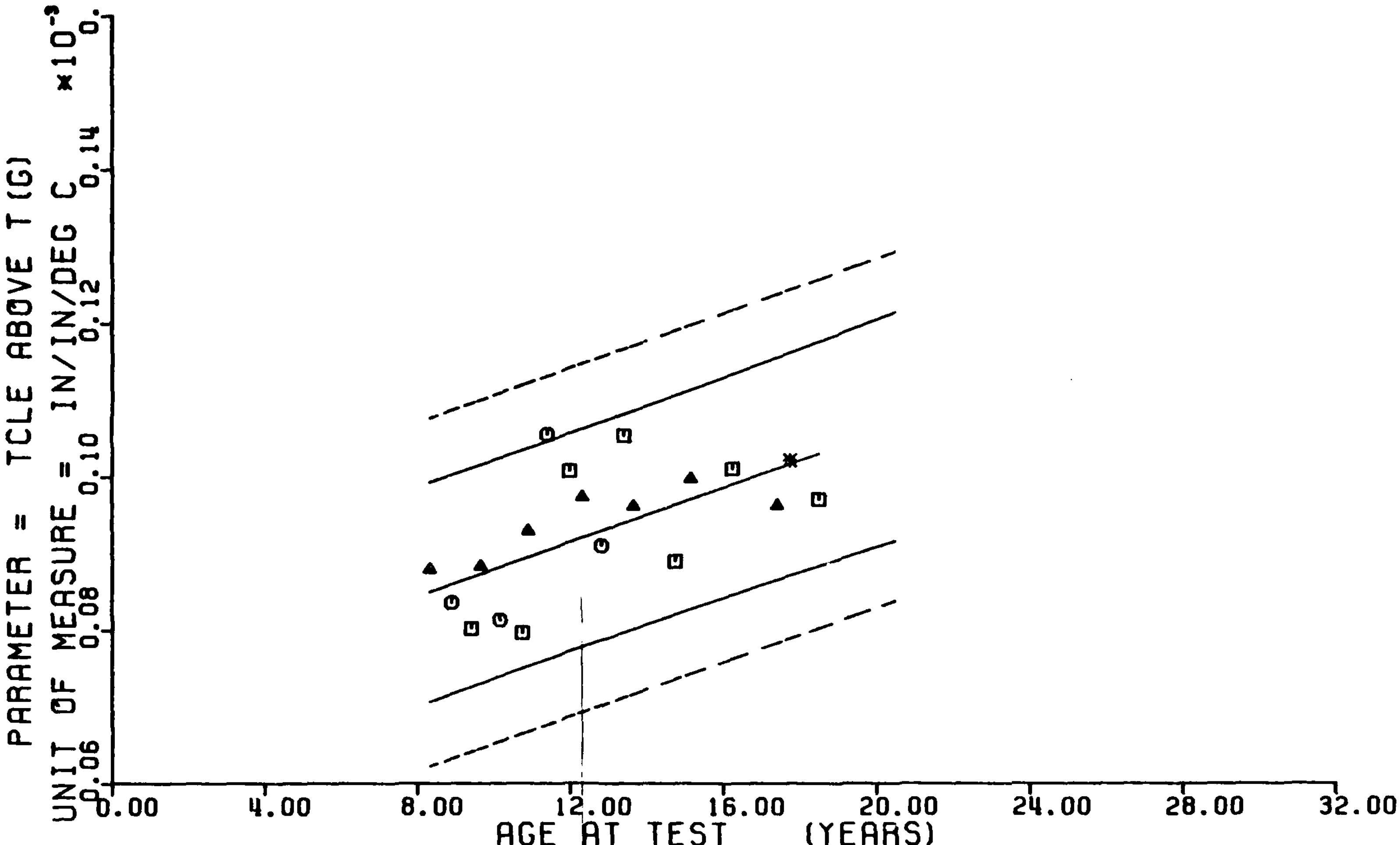
F = +3.8781607E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +9.3571684E-06

R = +5.9708363E-01 SIGNIFICANCE OF R = SIGNIFICANT S_b = +2.3636546E-08

t = +6.2274880E+00 SIGNIFICANCE OF t = SIGNIFICANT S_e = +7.5595490E-06

N = 72 DEGREES OF FREEDOM = 70

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 5 DEGREES C/MIN



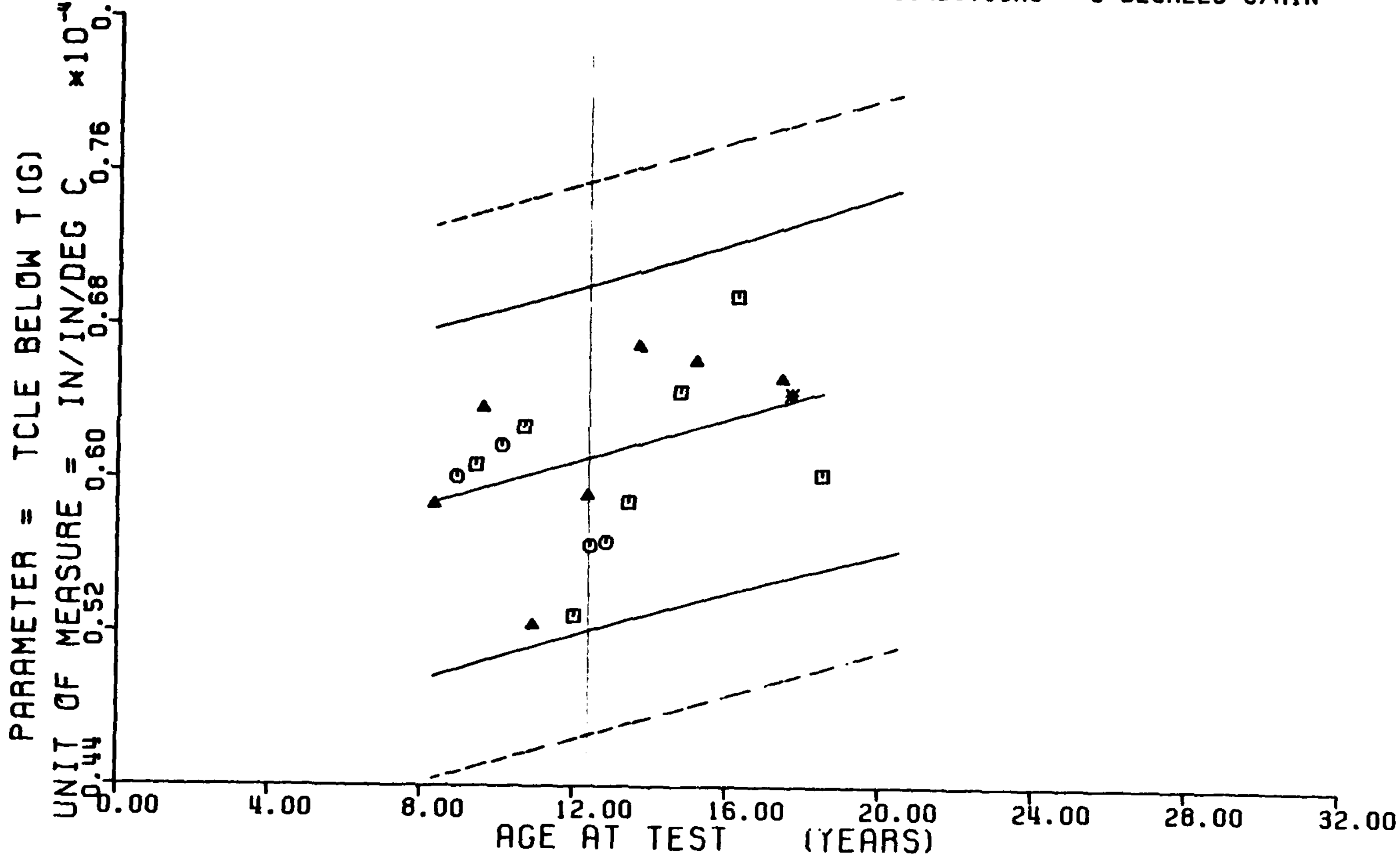
STAGE II DISSECTED MTRS,OUTER,THERMAL COEFFICIENT OF LINEAR EXPANSION ABOVE TG

Figure 50

Y = ((+5.4009051E-05) + (+4.7464224E-08) × X)

F = +1.0102229E+01   SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +5.0925603E-06
R = +3.5293296E-01   SIGNIFICANCE OF R = SIGNIFICANT S_B = +1.4933368E-08
t = +3.1784004E+00   SIGNIFICANCE OF t = SIGNIFICANT S_E = +4.7982849E-06
N = 73   DEGREES OF FREEDOM = 71

STORAGE CONDITIONS = AMB TEMP/RH   TEST CONDITIONS = 5 DEGREES C/MIN



STAGE II DISSECTED MTRS, INNER, THERMAL COEFFICIENT OF LINEAR EXPANSION BELOW TG

Figure 51

Y = ((+7.5689416E-05) + (+1.1752318E-07) * X)

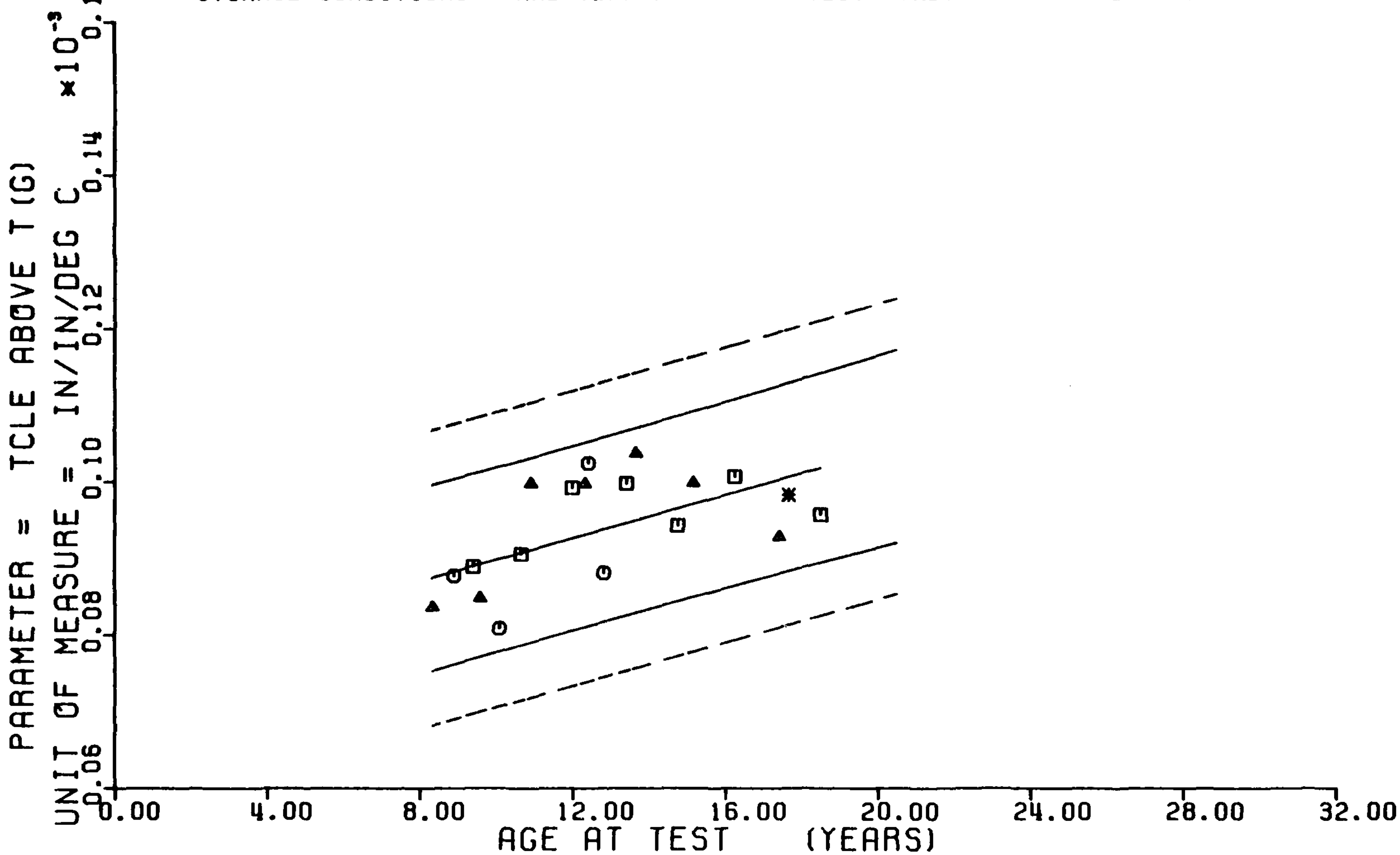
F = +3.4641841E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = +7.7714677E-06

R = +5.7264108E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +1.9967470E-08

t = +5.8857319E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +6.4158074E-06

N = 73 DEGREES OF FREEDOM = 71

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = 5 DEGREES C/MIN



STAGE II DISSECTED MTRS, INNER, THERMAL COEFFICIENT OF LINEAR EXPANSION ABOVE TG

Figure 52

Y = ((+6.8556856E+01) + (-1.1178789E-02) * X)

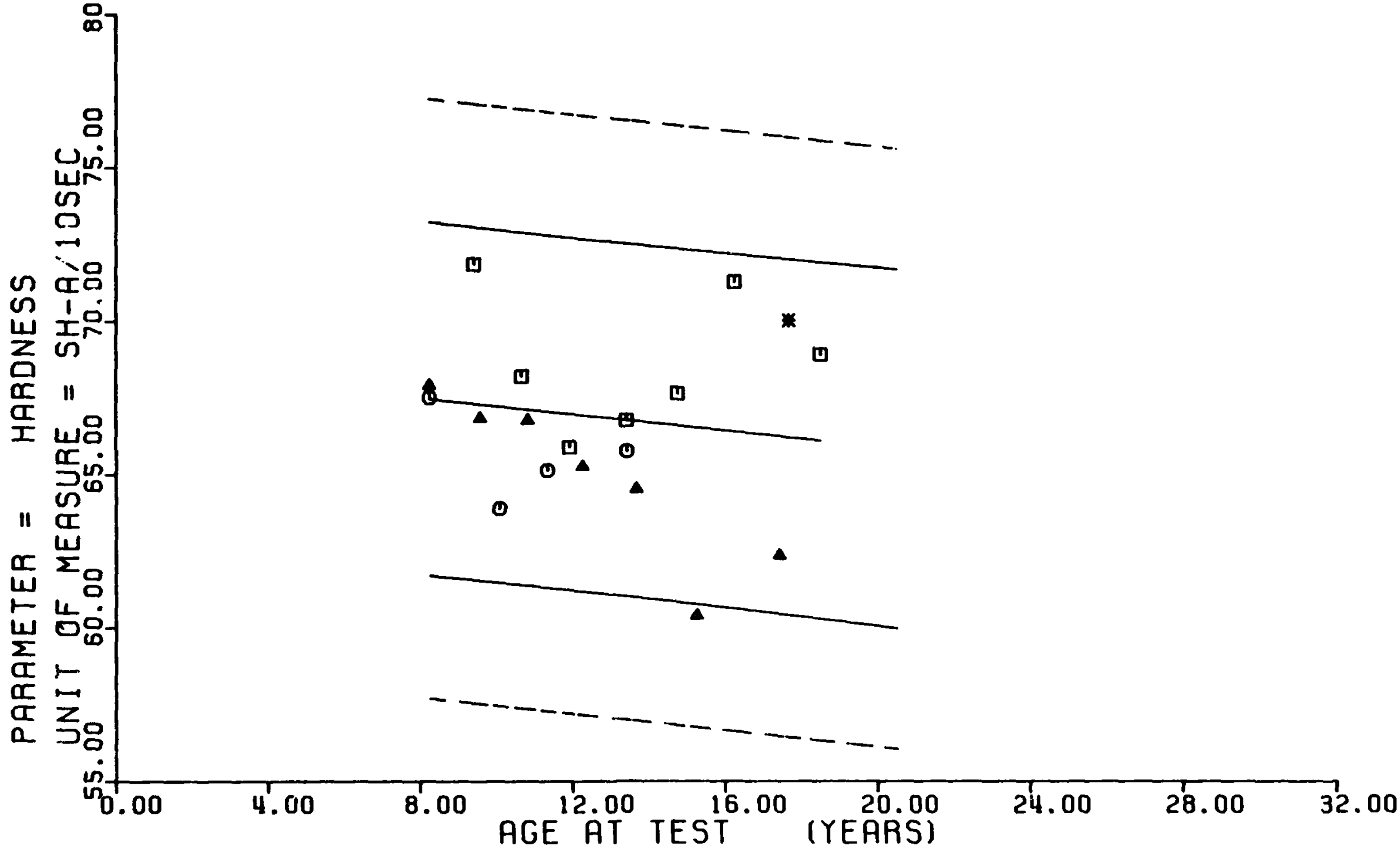
F = +3.5108245E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +3.2738242E+00

R = -1.2944978E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +5.9660955E-03

t = +1.8737194E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +3.2541480E+00

N = 208 DEGREES OF FREEDOM = 206

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTAS ONLY, OUTER, HARDNESS, NON-ORNTD, SHORE-A, 10-SEC.

Figure 53

Y = ((+6.0997871E+01) + (+1.7014528E-02) * X)

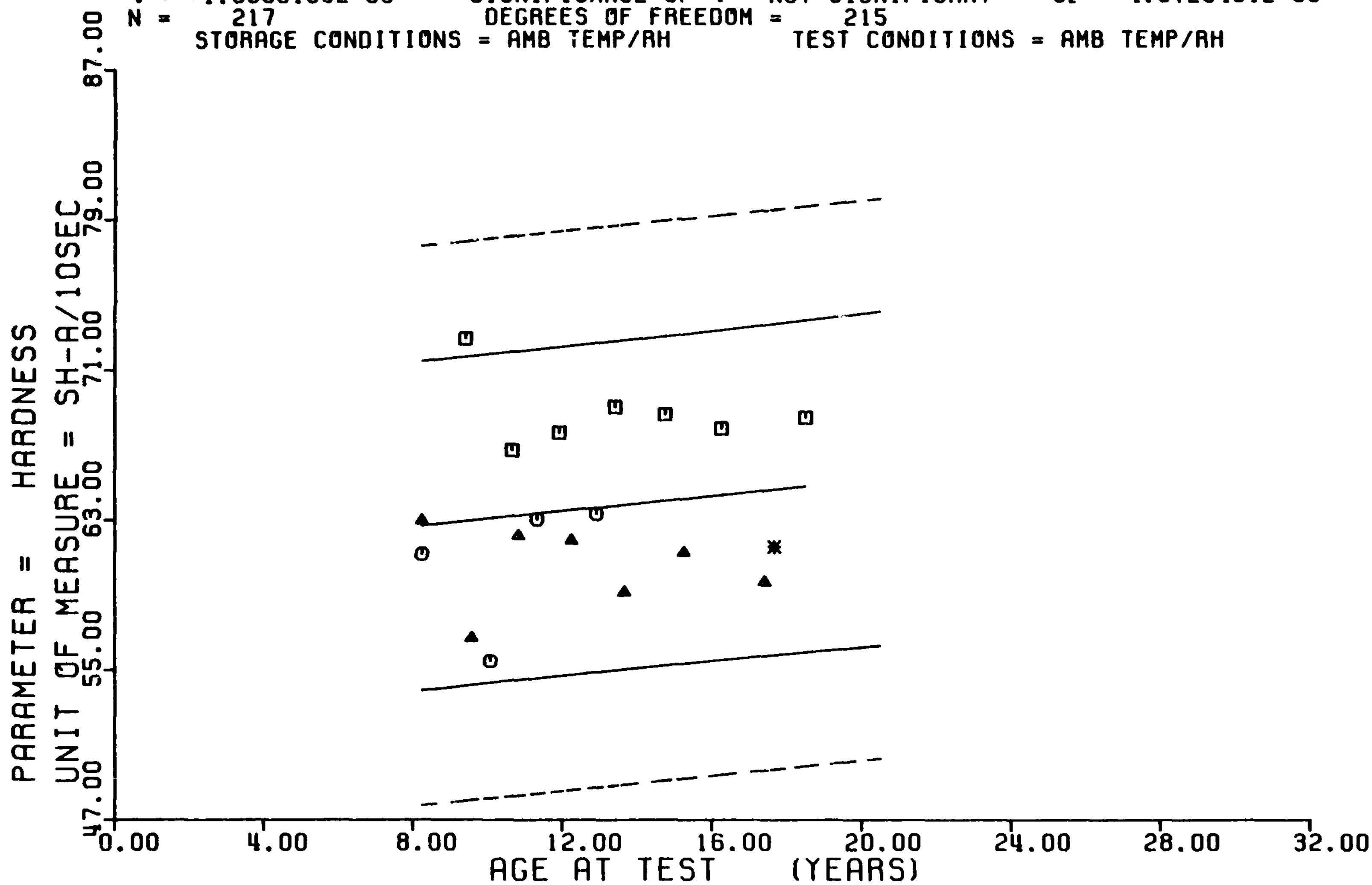
F = +3.5344510E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +5.0016339E+00

R = +1.2717479E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +9.0502159E-03

t = +1.8800135E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +4.9725461E+00

N = 217 DEGREES OF FREEDOM = 215

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH



II STAGE DSCT MTRS ONLY, INNER, HARDNESS, NON-ORNTD, SHORE-A, 10-SEC.

Figure 54

LOG(LOG Y) = (1.160176) + (-0.021398) * 12(X)

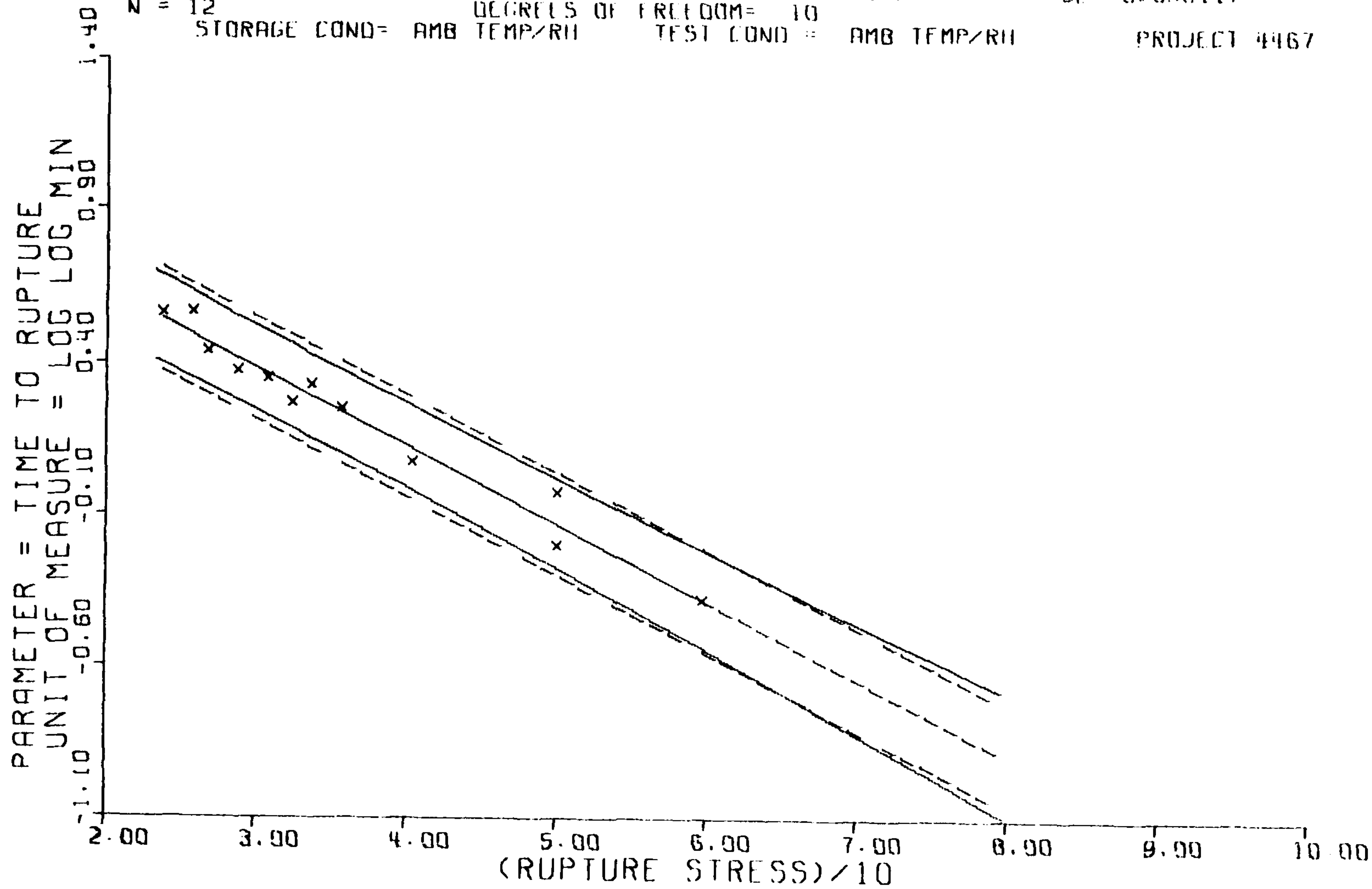
F = 290.717163 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = 0.295140

R = -0.983232 SIGNIFICANCE OF R = SIGNIFICANT S_a = 0.001255

t = 17.050430 SIGNIFICANCE OF t = SIGNIFICANT S_t = 0.056447

N = 12 DEGREES OF FREEDOM= 10

STORAGE COND= AMB TEMP/RH TEST COND = AMB TEMP/RH PROJECT 4467



STAGE 2 SAFEGUARD CONSTANT LOAD CASEBOND TENSILE, MOTOR 0022135

Figure 55

LOG(LOG Y) = (1.085882) + (-0.017308) * 12(X)

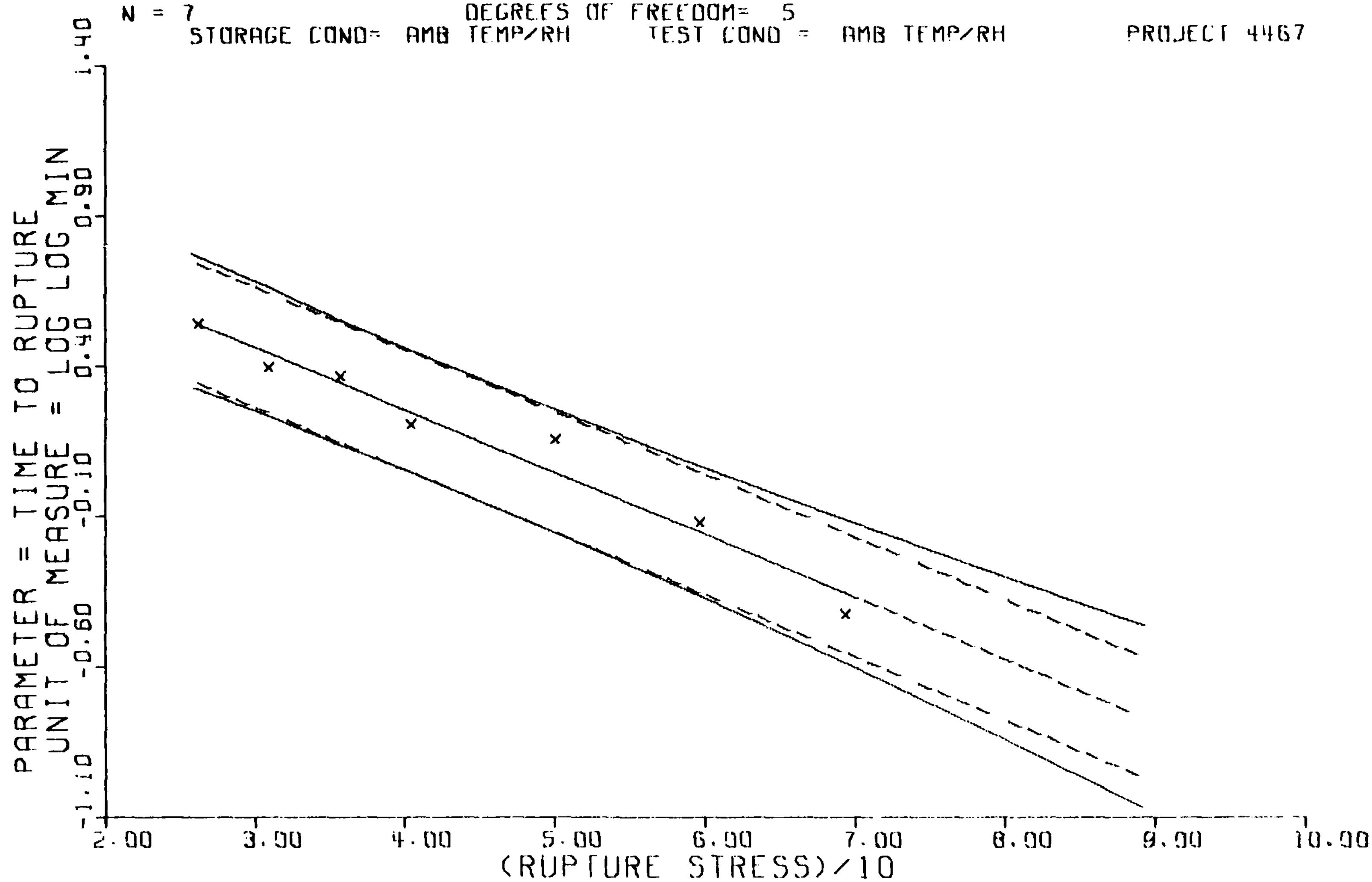
F = 145.939575 SIGNIFICANCE OF F = SIGNIFICANT σ_Y = 0.332563

R = -0.983298 SIGNIFICANCE OF R = SIGNIFICANT S_B = 0.001433

t = 12.080547 SIGNIFICANCE OF t = SIGNIFICANT S_F = 0.066305

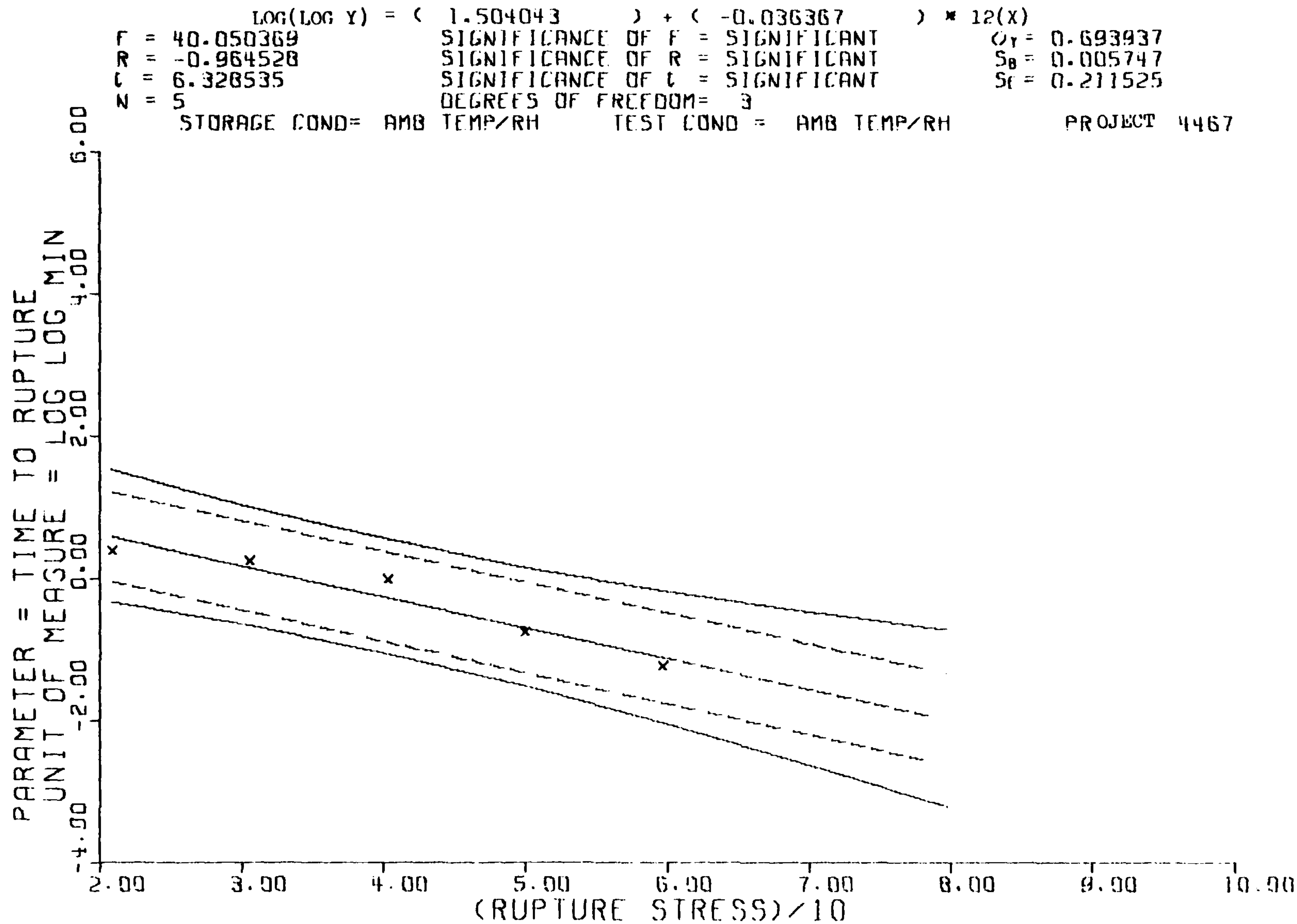
N = 7 DEGREES OF FREEDOM= 5

STORAGE COND= AMB TEMP/RH TEST COND = AMB TEMP/RH PROJECT 4467



STAGE 2 SAFEGUARD CONSTANT LOAD CASEBOND TENSILE. MOTOR 0022687

Figure 56



STAGE 2 SAFEGUARD CONSTANT LOAD CASEBOND TENSILE. MOTOR 0022788

Figure 57

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Dissected Motor Solid Propellant
Minuteman Safeguard

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains the data obtained from testing propellant and case bond materials from four dissected Minuteman Stage II Motors. The tests conducted were in accordance with Service Engineering (MMWRBA) General Test Directive GTD-1 Dissect dated 28 June 1974. The directive specifies the tests required to elucidate any age induced problems which may affect the service life of the Stage II Motor.

Linear regression analysis was used to indicate trends of the test parameters. A representative regression plot was made of several parameters with

each motor tested to date identified by different symbols. The regression analysis normally verified the trends established during the last test phase. Although there were some trend changes either from or to significant status, it does not seem likely that any problems of major concern are apparent at this time.

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